

“UPRM Progres/Final Report”

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Summary

This year the University of Puerto Rico at Mayaguez (UPRM) High Energy Physics (HEP) group continued with the ongoing research program outlined in the grant proposal. The program is centered on the Compact Muon Solenoid (CMS) experiment at the proton-proton (pp) collisions at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. The main research focus is on data analysis and on the preparation for the High Luminosity (HL) LHC or experiment detector upgrade.

The physics data analysis included Higgs Doublet Search and measurement of the (1) Λ_b^0 branching fraction, (2) B meson mass, and (3) hyperon Ξ_b^- lifetime. The detector upgrade included work on the preparations for the Forward Pixel (FPX) detector Silicon Sensor Testing in a production run at Fermilab. In addition, the group has taken responsibilities on the Software Release through our former research associate Dr. Eric Brownson who acted until last December as a Level Two Offline Manager for the CMS Upgrade.

In support of the CMS data analysis activities carried out locally, the UPRM group has built and maintains an excellent Tier3 analysis center in Mayaguez. This allowed us to analyze large data samples and to continue the development of algorithms for the upgrade tracking robustness we started several years ago, and we plan to resume in the near future. This project involves computer simulation of the radiation damage to be suffered at the higher luminosities of the upgraded LHC.

This year we continued to serve as a source of outstanding students for the field of high energy physics. Three of our graduate students finished their MS work in May, 2014, Their theses research were on data analysis of heavy quark b-physics. All of them are currently enrolled at Ph.D. physics program across the nation. One of them (Hector Moreno) at New Mexico University (Hector Moreno), one at University of New Hampshire (Sandra Santiesteban) and one at University of Puerto Rico-Rio Piedras (Carlos Malca). The students H. Moreno and C. Malca has been directly supervised by Dr. Mendez and S. Santiesteban supervised by Dr. Ramirez. During the last 13 years, our group have graduated 23 MS students on experimental High Energy Physics data analysis and applied hardware techniques. Most of the students have been supported by DOE grants, included this grant. Since 2001, Dr. Mendez have directly supervised eleven students, Dr. Ramirez three students and the former PI (Dr. Lopez) nine students. These theses work are fully documented in the group web page (<http://charma.uprm.edu>).

The High Energy Physics group at Mayaguez is small and presently consists of three Physics faculty members, the Senior Investigators Dr. Hector Mendez (Professor) and Dr. Juan Eduardo Ramirez (Professor), and Dr. Sudhir Malik who was just hired in July 2014. Dr. Ramirez is in charge of the UPRM Tier-3 computing and will be building the network bandwidth infrastructure for the campus, while Dr. Mendez will continues his effort in finishing the heavy quark physics data analysis and moving to work on SUSY analysis for the 2015 data.

Our last grant application in 2012 was awarded only for 2013-2014. As a result our postdoc position was lost last month of March. Since then, we have hired Dr. Malik as a new faculty in order to reinforce the group and to continue our efforts with the CMS experiment. Our plan is to hire another junior faculty in the next two years to strengthen the HEP group even further.

Dr. Mendez continues with QuarkNet activities involving an ever larger group of high school physics teachers from all around Puerto Rico.

Progress Report

Since UPRM joined CMS in 2006, the group has been contributing to the experiment in several areas, including physics analysis, detector building, maintenance and performance, software and service work. Fifteen graduate students have already received their MS degree so far with physics analysis and instrumentation projects done at CMS. Six of them were directly supervised by the PI (Dr. Mendez) of this proposal and three directly supervised by the co-PI (Dr. Ramirez).

I. Physics Analysis

(a) **Higgs Doublet Search** (E. Browson)

Dr. Eric Browson, as a UPRM postdoc, was also recently involved in a search for an extension of Higgs sector to two Higgs doublet models (2HDMs) in several upgrade LHC environments. In this study the Heavy Higgs (H) and A-particles in the 2HDMs decayed into two Standard Model Higgs (h) (H to hh) and Z boson and h (A to Zh). The result of this work was shown in the Snowmass Conference last 2013 summer [1, 2, 3]. Dr. Brownson was fully supported for 8 months (August-2013 to March-2014) by this grant.

(b) Λ_b^0 **Analysis** (H. Mendez, M. Falla, H. Moreno)

The group have been actively working at the experiment B-Physics group doing analysis on $\Lambda_b^0 \rightarrow \Lambda^0 \mu^+ \mu^-$ rare decays. We are in the process of taking a closer look into this decay process, and purifying the Λ_b^0 signal from the most copiously "charmed" decays produced $\Lambda_b^0 \rightarrow \Lambda^0 J/\psi$. The group has presented already and discussed this work in the collaboration B physics group. The analysis is almost done and we are in the approval process of publishing the analysis. UPRM is the solely responsible institution for the Λ_b^0 analysis. Two graduate students (M. Falla & H. Moreno) have received their Master's degrees based on the preliminary work done on this analysis. Falla and Moreno graduated in the spring of 2013 and 2014 respectively. Both of them have been supported by our previous DOE grant, although Moreno received partial support by this grant for his last year at graduate school.

(c) Ξ_b^- **Analysis** (E. Ramirez, S. Santiesteban)

The group have been also working on the Ξ_b^- lifetime measurement. A preliminary measurement of its baryon lifetime through the decay chain $\Xi_b^- \rightarrow \psi \Xi^0$ has been done using the 2011 CMS dataset at 7 TeV. The final state included $J/\psi \rightarrow \mu^+ \mu^-$, $\Xi^0 \rightarrow \Lambda^0 \pi^-$ and $\Lambda^0 \rightarrow p \pi^-$. After the reconstruction and selection, 65 Ξ_b^- candidates were found at the nominal mass. This work is in progress and was directly supervised by Dr. Ramirez and developed by the graduate student S. Santiesteban. Santiesteban was fully supported for 1 year by this grant.

(d) **B Meson Mass** (H. Mendez, C. Malca)

We have done also a preliminary measurement of the mass of the B^+ meson produced in pp collision at centre-of-mass energy of 7 TeV. This measurement has also been done with

high precision by many other experiments and this measurement is very competitive with others, in particular with the LHCb result. in addition to be in a complementary kinematics region. This work is in progress and is supervised by Dr. Mendez and developed by C. Malca. Malca was not funded by this grant due to lack of funds.

All of these projects are fully documented and available in the group web page: <http://charma.uprm.edu>.

II. Performance Studies

• **Sensor Test** (H. Mendez, C. Huerta)

Last summer (May-July 2014) the group, including graduate student Connet Huerta, worked on the preparations for the Forward Pixel (FPIX) detector Silicon Sensor Testing in a production run at Fermilab for the upgrade. This work was done at the SIDET facility at Fermilab. The CMS pixel detector is the first component to interact with the particles created in the collision; therefore, a hardware upgrade is necessary to maintain tracking performance in light of the increased order of magnitude of the luminosity. The silicon detector system is currently being upgraded to function properly at the high energy frontier. Although pixelated silicon detector technology is mature, there is an ongoing effort to go from the initial R&D to a stable production operation. In this effort, it is important to address issues that contribute to increased noise and an increased uncertainty in calibration, which, as a consequence, increase transverse momentum measurement smearing.

A deep understanding of issues in the hardware development phase will be of great use to data interpretation and understanding the physics in the 2015 increased luminosity and energy LHC run, hence the importance of preparations for the testing phase. The quality of a silicon sensor is central to the proper function of a silicon detector. In HEP applications, it is standard to check the quality of a silicon sensor by analyzing its I vs V and C vs V curves in reverse bias. The scope of the undertaken project was to prepare an experimental set-up to realize testing through the aforementioned analysis, allowing us to check the quality of the silicon sensors.

The project was advised by Dr. Mendez, and Dr. Leonard Spiegel, Scientist (II) of Fermilab. The objectives set forth for the project are listed here and were to be accomplished between May and August: (1) become familiar in operating the Cascade probe station at SiDet and handling FPIX silicon sensor wafers, (2) automate the site to site movement for I vs V and C vs V measurements, (3) generate XML files and upload them to the database, and, time permitting, (4) implement a matrix switch to change from I vs V to C vs V measurements in an automated manner.

Technical aspects of the project were presented on the July 15-16 LPC "Tracker Upgrade + Hardware Experience" Hands-on Advanced Tutorials Session. In said event, we demonstrated the sharp temperature dependence of the leakage current in silicon sensors using the temperature-tunable chuck on the Cascade system. A summary of the project was presented to the FPIX Upgrade U.S. Collaboration Meeting.

In conformance with a plan for continuous improvement, there are follow up tasks that will be undertaken. One such task is that XML file upload needs to be tested; where sensor IV and CV tables for this purpose were defined last summer. It is essential to realize cross calibration of a Sintef wafer with Purdue. Point 4 from the project objectives list is pending. These tasks will be facilitated through the continued involvement of UPRM in probing production sensors. C. Huerta continues as graduate student at UPRM. Huerta was fully supported for the summer by the non-cost extension of this one-year grant.

III. Software Release Manager

- **Software for Upgrade** (E. Brownson)

With the upgrades to the LHC getting ever closer, design choices for the upgrades to CMS are looming. Of course before any design choice is made, detailed simulations must be carried out. In this role, as both a Release Manager and Level Two Offline Manager for the Upgrades, Brownson has led many efforts to properly simulate potential upgrade designs. Not only must upgrade detectors be properly simulated, every design presents its own challenges and opportunities in event reconstruction and our current algorithms must be adapted to them. During the past few years, UPRM has been involved in creating seventy-two software releases for upgrade studies. With each release new compatibilities and capabilities are added.

Brownson has been particularly involved in getting the tracking algorithms to run on potential upgrades to the tracking system. Both in terms of the low level detector resolutions and the high level tracking routines. Being located at the LPC, Fermilab has allowed him to work closely with other researchers and provide support for their studies. With the closing of the grant, UPRM has chosen not to pursue another term as a manager for the upgrade simulations, and therefore those duties were handed over to others at the start of January 2014. This has also prevented him from taking the lead in generating further studies, but he has contributed greatly to their advancement. Brownson did not abandon his role within the simulations group, but has continued to be a resource for all those beginning their studies of upgrades.

Bibliography

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