LHCb - study of hadron production, heavy flavour physics and the upgrade program - team, year 2016 and future plans

Florin MACIUC on behalf of the Romanian LHCb group

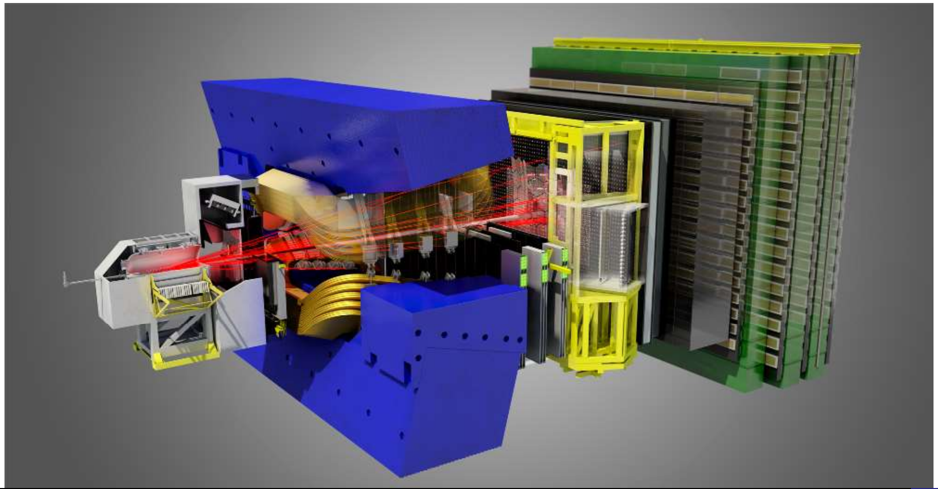
Horia HulubeiNational Institute of Physics and Nuclear Engineering IFIN-HH

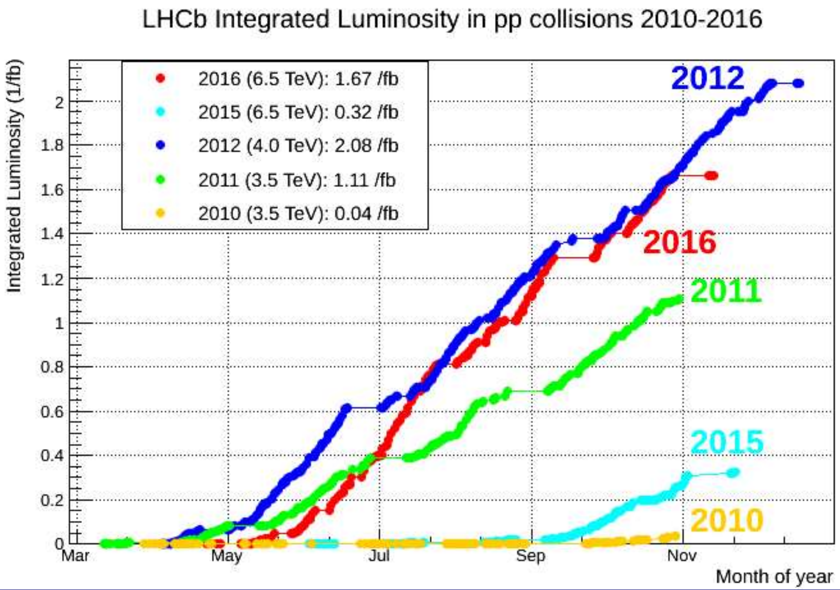
ISAB Meeting

November 14th, 2016

LHCb

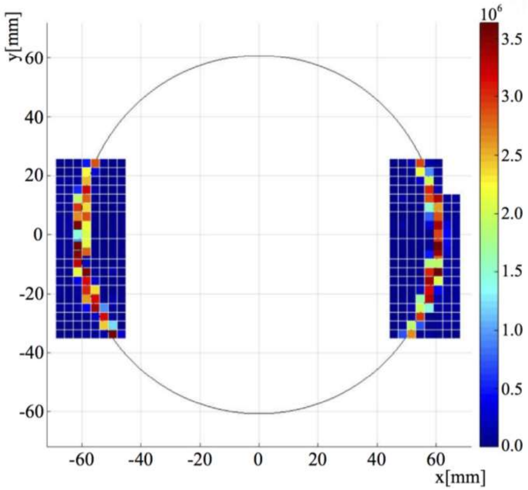
1. A Total of 342 papers and 14068 citations by beginning of November 2015.
   - Already more than 50 papers published this year..
2. Highlights of this year:
   - More than 1.5 fb^{-1} recorded luminosity at LHCb in 2016, almost 2 fb^{-1} at 13 TeV proton-proton.
   - b-hadron production and 13 TeV
   - Charm time asymmetries
   - New charm CPV and asymmetry measurements
   - Exotic-like particles
   - Tetraquarks and Pentaquarks
   - Ridge in proton-ion collisions near-side ridge

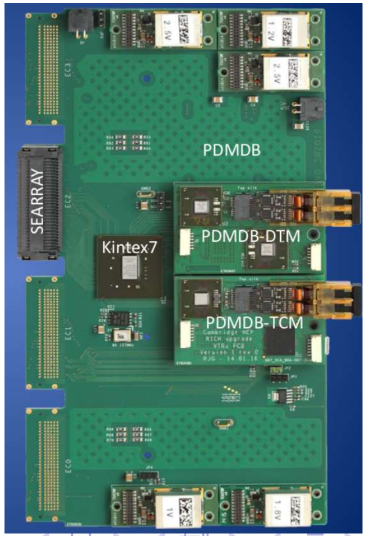




LHCb - Photon Detector Module and Digital Board

1. The Upgrade program picking speed at an accelerated rate.
   - Beam tests on LHCb-RICH elementary cells with Hamamatsu Multi-anode-Photo-Multiplier Tubes (MaPMTs), irradiation tests;:
   - radiation-hardness studies on frontend electronics and FPGA for PDMDB digital boards (us);
   - PRR of PDM and EDR of PDMDB ;
   - MaPMTs, DC-DC and GBTx started to arrive
   - RICH PDM test beam paper 2014 JINST, ongoing
   - All Upgrade expenses approved by national funding agencies.
   - Phase II and Phase Ib Upgrades discussions - HC-LHC -.300 fb^{-1}?





LHCb-RO

1. Summary of our group activities/results in 2016:
   - Radiation hardness tests at Louvain; UCL - HIF and Paul Scherrer Institut. - PIF facilities
   - 2 FPGA PCBs and 3 FPGA PCBs tested with 100s MeV ions and 200 MeV protons, respectively.
   - Firmware programming for Kintex-7 FPGA, several versions testing CRAM, BRAM, IO, Flip-Flops;
   - Engineer Design Report EDR
   - One WLCG GRID site Ro-11, Tier-2, maintained and serviced for LHCb collaboration exclusively for Monte Carlo LHCb production and User jobs - LHCb Virtual Organization.
   - Computing tasks for LHCb collaboration: HepData, Monte Carlo tools, RIVET and LHCb software integration, tuning.
   - Partnership:with "Stefan cel Mare" University of Suceava - one common Workshop organize in Suceava.
   - Outreach events.

LHCb-RO

- 3 new papers, 3 papers in preparation with NIM A as target journal,
- aiming with USV group to send new papers to Romanian Journal of Physics
- 1 internal LHCb-referee jobs for two LHCb analyses, 3 internal reviews for LHCb papers by our group.
- 10 talks given at International Conferences and Workshops.
- tens of talks at LHCb Physics Work Group meeting at CERN
- One of our colleagues, Alex Grecu, is convener for soft-QCD WG physics analyses; MC contact for soft-QCD Work Group: Alex Grecu.
- New members:
  - IFIN-HH: new 2 PhD students, 1 new Post Doc, a new thesis defense is next,
  - University of Suceava: 3 new members, one PhD student defended successfully his thesis

Group Members

- The LHCb Bucharest and Suceava group is formed by 18 members: 7 physicists, 6 PhD students, 1 MSc student, 2 WLCG Grid and Programming staff experts, one beam and irradiation expert, and one accounting staff specialist.
- Quota of a second LHCb project (UEFISCDI project[1]) is included in Full Time Equivalent (FTE) ratio,

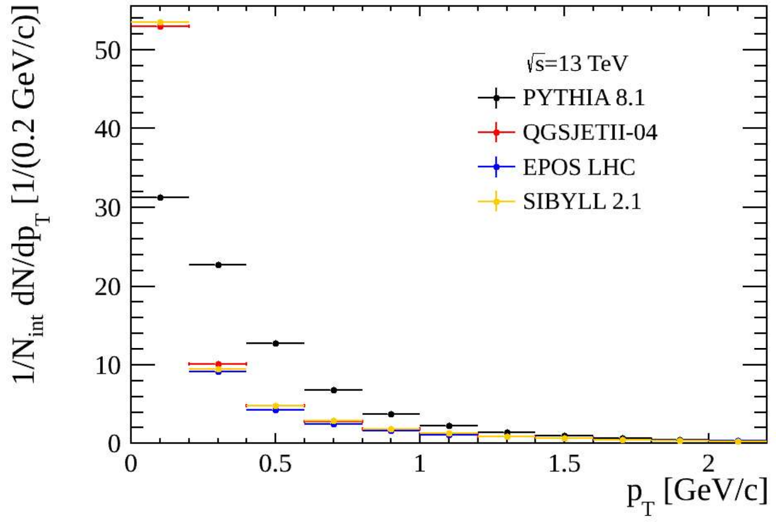
No	Name	position	ratio FTE and domain
1	Florin MACIUC	physicist	10 % analysis and 40 % R&D (40 % analysis other LHCb project)
2	Alexandru Tudor GRECU	physicist	45 % analysis (45 % other LHCb project)
3	Mihai STRATICIUC	physicist	50 % R&D
4	Lucian-Nicolae COJOCARIU	PhD student	90 % R&D for Upgrade 10 % other LHCb project
5	Vlad PLACINTA	PhD student	90 % R&D for Upgrade 10 % other LHCb project
6	Lavinia Elena GIUBEGA	PhD student	50 % analysis (50 % other LHCb project)

Group Members

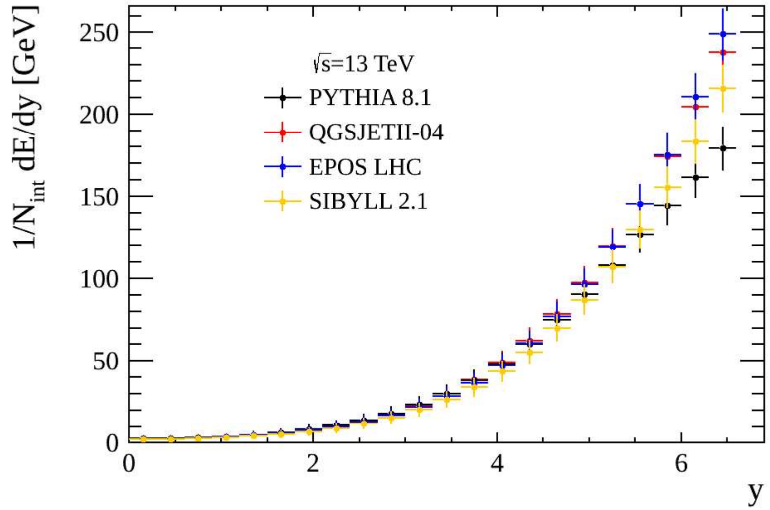
7	Alex Catalin ENE	PhD student	50 % analysis 50 % other LHCb project
8	Laurentiu DUMITRU	staff	50 % LHCb Online, admin. R&D Upgrade
9	Teodor IVANOAICA	programmer admin	20 % LHCb Grid (20 % other LHCb project)
10	Nicoleta-Ileana DUMITRU	staff	30 % accounting
11	Ovidiu HUTANU	M.Sc. student	10 % R&D for Upgrade
12	Mihai Dimian	physicist	8 % analysis and 10 % R&D
13	Cristian Andy TNASE	researcher	30 % R&D
14	Cristian PIRGHIE	physicist	28% analysis
15	Camelia PIRGHIE	physicist	30 % analysis
16	Marius PRELIPCEANU	researcher	30 % R&D
17	Dorin-Andrei ANTONOVICI	PhD student	26% R&D
18	Adrian BODNRESCU	PhD student	28% analysis

Particle production simulations for PYTHIA and CRMC generators at knee - new PhD study

1. One of our new PhD students just started an introductory work into the physics of particle production:
   - task is to generate data with few Cosmic ray generators in CRMC and compare with PYTHIA, LHCb and default tune;
   - analyze directly HepMC data for greater detail;
   - harmonize the final state definition over generators.



Stable particle p_T in generators for Minimum-Bias events at 13 TeV pp



Energy flow at 13 TeV

HepData repository

1. LHCb liaison to HepData, 16+ new LHCb entries in repository.
    - "Measurement of $\psi(2S)$ meson production in pp collisions at $\sqrt{s} = 7$ TeV", Eur. Phys. J. C72 (2012) 2100;
    - "Observation of double charm production involving open charm in pp collisions at $\sqrt{s} = 7$ TeV", JHEP 1206 (2012) 141; Addendum: JHEP 1403 (2014) 108;
    - "Measurement of the fraction of $\Upsilon(1S)$ originating from $\chi_b(1P)$ decays in pp collisions at $\sqrt{s} = 7$ TeV", JHEP 1211 (2012) 031;
    - "Measurement of J/ψ production in pp collisions at $\sqrt{s} = 2.76$ TeV", JHEP 1302 (2013) 041;
    - "Measurement of the $\chi_b(3P)$ mass and of the relative rate of $\chi_{b1}(1P)$ and $\chi_{b2}(1P)$ production", JHEP 1410 (2014) 88;
    - "Measurement of the $\eta_c(1S)$ production cross-section in proton-proton collisions via the decay $\eta_c(1S) \to p\bar{p}$", Eur.Phys.J. C75 (2015) no.7, 311;
    - "Measurement of B_c^+ production in proton-proton collisions at $\sqrt{s} = 8$ TeV", Phys.Rev.Lett. 114 (2015) 132001;
    - "Measurement of the forward Z boson production cross-section in pp collisions at $\sqrt{s} = 7$ TeV", JHEP 1508 (2015) 039;
    - "Forward production of Υ mesons in pp collisions at $\sqrt{s} = 7$ and 8TeV", JHEP 1511 (2015) 103;
    - "Measurements of prompt charm production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV", JHEP 1603 (2016) 159;

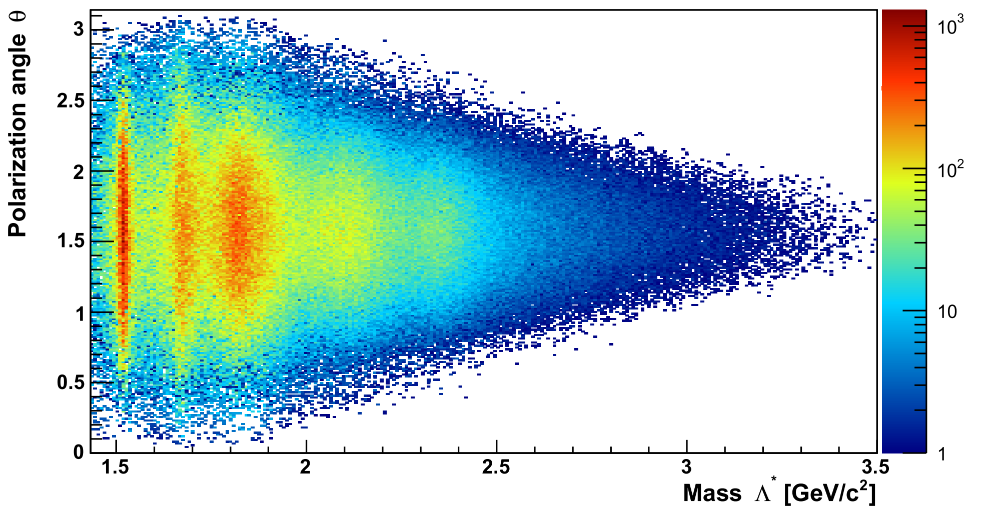
HepData repository

1. LHCb liaison to HepData, 16+ new LHCb entries in repository.
   - "Production of associated Υ and open charm hadrons in pp collisions at $\sqrt{s} = 7$ and 8 TeV via double parton scattering", JHEP 1607 (2016) 052;
   - "Measurement of forward W and Z boson production in pp collisions at $\sqrt{s} = 8$ TeV", JHEP 1601 (2016) 155;
   - "Angular analysis of the $B^0 \to K^{*0}\mu^+\mu^-$ decay using 3 fb^{-1} of integrated luminosity", JHEP 1602 (2016) 104;
   - "Measurements of prompt charm production cross-sections in pp collisions at $\sqrt{s} = 5$ TeV", arXiv:1610.02230 [hep-ex];
   - "Measurement of the exclusive Υ production cross-section in pp collisions at $\sqrt{s} = 7$ TeV and 8 TeV", JHEP 1509 (2015) 084;
   - "Measurement of forward J/ψ production cross-sections in pp collisions at $\sqrt{s} = 13$ TeV", JHEP 1510 (2015) 172;

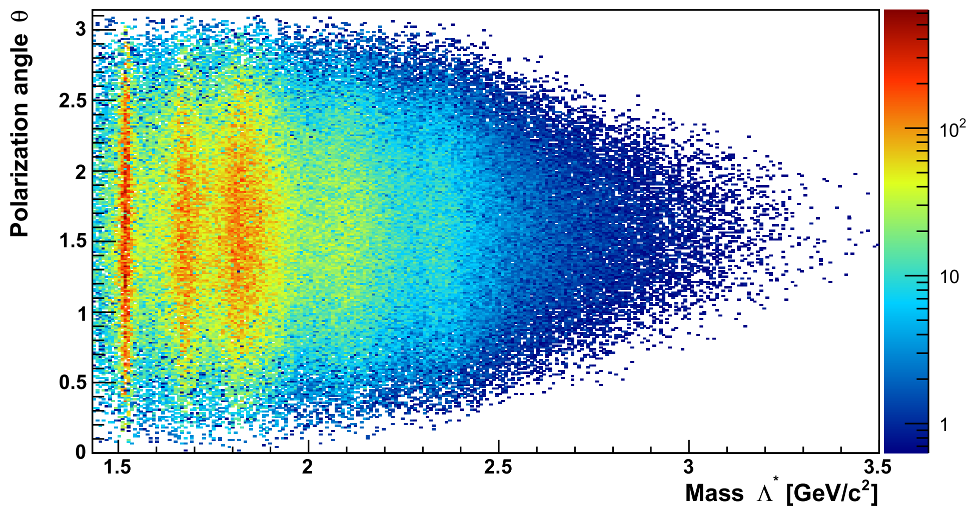
Rare Decays - Angular analyses of $\Lambda_b \to \Lambda^*\gamma$ decays and beyond

- Analyses of resonances in $\Lambda_b \to \Lambda^*(p^+K^-)\gamma$, with various spin values, from spinor case to J=9/2 tensors.
- Weighted s-wave component events in MC sample through:a mass term which is a relativistic Breit-Wigner form times a function of polarization angle.
- Few polarization configuration generated, plus acceptance and efficiency studies ongoing

Λ^* mass spectrum for $M(p^+K^-)$;and polarization angle θ generated samples of $\Lambda_b \to p^+K^-\gamma$ s-wave and emulation of 12 Λ^* intermediate states, an extreme case of polarization

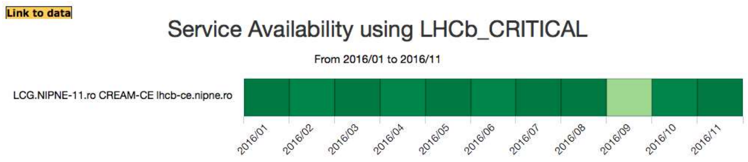


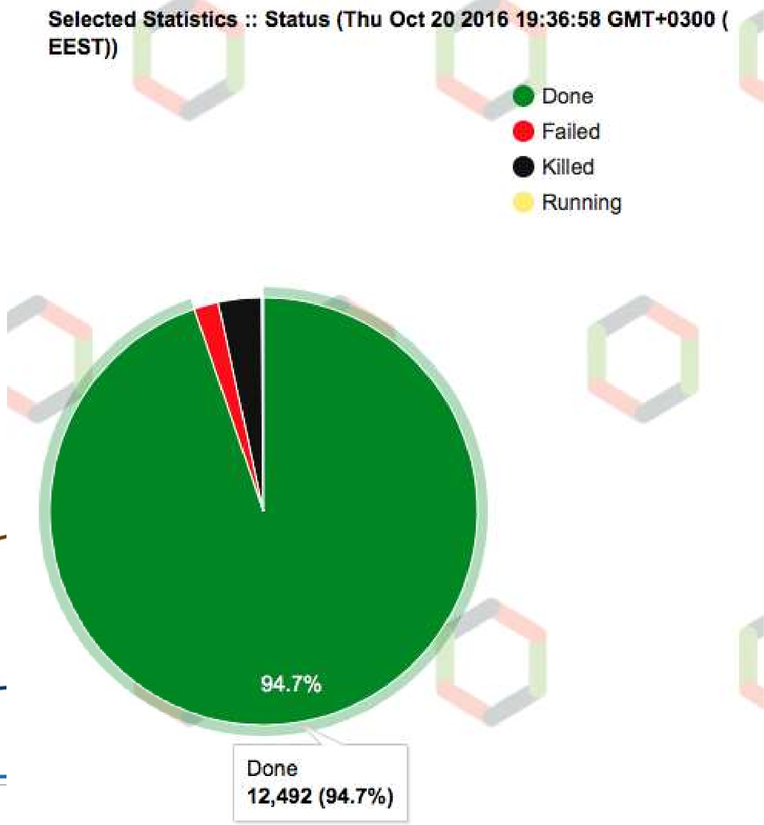
, Λ^* mass spectrum for $M(p^+K^-)$;and polarization angle θ generated samples of $\Lambda_b \to p^+K^-\gamma$ s-wave and emulation of 12 Λ^* intermediate states, no polarized state

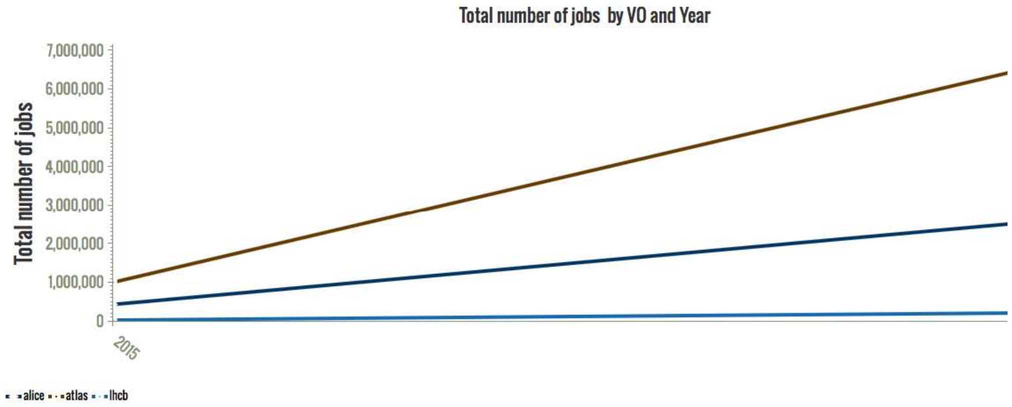


Computing

- **Ro-11** Though we had issues caused by the NGI coordination by ICI, the site managed to get the highest Normalized CPU time (kSI2K) ever..
- At this time it is over 2 000 000 kSI2K hours, and load is constant over 2016.
- Continue maintenance of few LHCb software packages and tools.

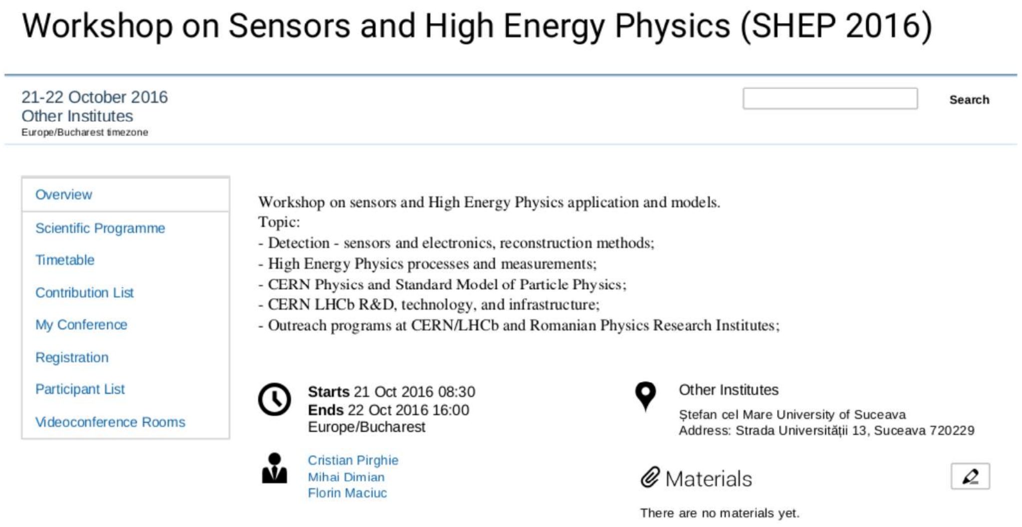






Outreach

- This year outreach events in Bucharest and Suceava:
- Researcher Night USV Suceava;
- Masterclass in March for SUCEAVA ro LHCb/CERN connection , 40 high-school students.
- The LHCb promotion made to the Olympic team in Astronomy and Astrophysics (juniors and seniors) during trainee-ship in June 2015 at Stefan cel Mare University of Suceava lecture (Very Early Universe and Elementary Particles);
- Promoted LHCb at the IOAA, IO 2016


Workshop on Sensors and High Energy Physics (SHEP 2016)

21-22 October 2016
Other Institutes
Europe/Bucharest timezone

Search

Overview
Scientific Programme
Timetable
Contribution List
My Conference
Registration
Participant List
Videoconference Rooms

Workshop on sensors and High Energy Physics application and models.
Topic:
- Detection - sensors and electronics, reconstruction methods;
- High Energy Physics processes and measurements;
- CERN Physics and Standard Model of Particle Physics;
- CERN LHCb R&D, technology, and infrastructure;
- Outreach programs at CERN/LHCb and Romanian Physics Research Institutes;

Starts 21 Oct 2016 08:30
Ends 22 Oct 2016 16:00
Europe/Bucharest

Cristian Pirghie
Mihai Dimian
Florin Maciuc

Other Institutes
Ştefan cel Mare University of Suceava
Address: Strada Universității 13, Suceava 720229

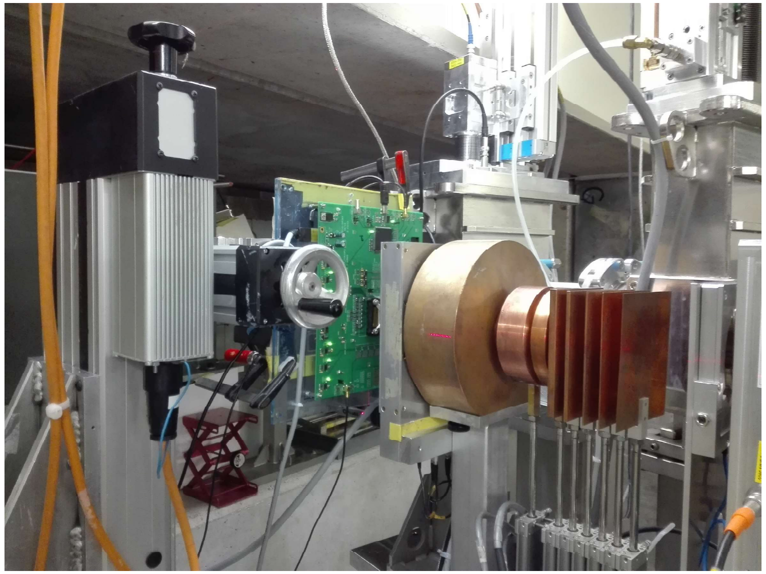
Materials
There are no materials yet.

Plan of physics analyses and objectives 2015/2016

1. Strangeness production like V0 at $\sqrt{s} = 13$ TeV, hyperon production in RUN 1 data.
2. Tuning of a proton-proton collisions event generator: PYTHIA 8 "LHCb-flavored" configuration.
3. LHCb measurements integration in HepData repository, together with RIVET plugin development.
4. Beauty hadron rare decays involving penguin-loop type of processes. The radiative decay studies will continue with integration in the larger work group.
5. Searches for new resonances and measuring properties of the known intermediate states of beauty and charm decays. At this stage it consists mostly of feasibility studies.
6. CRMC - EPOS, QGSJet, SYBILL - and PYTHIA, physics description of the proton-proton collision with possible extension to proton-ion. The intent here is to use some of the cosmic ray physics to improve the LHCb Monte Carlo event description and also use some for the air shower measurements information if possible.

R&D studies and Upgraded Detector construction

1. Radiation harness test for IC: FPGA and ASICs: Julic and Legnaro testing and possible one or two other facility application.
2. Test bench for MaPMT aging studies and radiation hardness.
3. Involvement into RICH-Upgrade construction: Photon Detector Module (PDM) construction and testing of individual components
4. PDMDB - digital board testing and firmware testing in radiation with high TID.
5. PDMDB construction and testing of optical link boards.
6. PDMDB - digital board test bench, design and beginning of actual mass testing.



Long Term Plans 2018-2019, Phase II in the HC-LHC time-frame

1. Transition form soft-QCD to hard-QCD and flavour processes for most team.
    - new charm and beauty decay studies, besides the production measurements;;
    - CPV and polarization;
    - Soft-QCD production measurements and various energies - PhD.
2. Phase I Upgrade of RICH detectors in the 2nd Long Shut Down - PDMDB testing, and assembly.
    -
3. Ro-11, Computing and Outreach activities;
4. Expansion and consolidation of the team.
5. Consider involvements n the phase II Upgrade program of RICH detectors. 10^{34} /cm^2/s luminosity, 300 fb^{-1}
    - RICH Upgrade Phase I and II.
    - SiPM - Silicon Photomultipliers, carbon fiber mirrors, new front-end electronics.
6. beyond 50 fb^{-1} in HL-LHC phase, formulate new physics goals..

LHCb-INT-20XX-YYY
June 27, 2016

RICH Upgrade PDMDB EDR - Kintex-7 FPGA Radiation Hardness Tests and Implications

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[1] *Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH)* [2] *Cavendish Lab (HEP) University of Cambridge* [3] *University Stefan cel Mare Suceava (USV).*

Abstract

We introduce the first tests done on a commercial FPGA device which is being considered for usage in the Digital Boards of the Upgraded LHCb-RICH Elementary Cells. We discuss the planning of future test and the conclusions so far.

1 Introduction

In any application concerning the accelerator science and experiments, a careful study of the radiation effects is crucial for a successful outcome of these type of endeavors, given the radiation induced processes taking place in the active volumes of sensors and electronics. The Integrated Circuits (IC) are especial susceptible to the hazardous conditions existent in large accelerator experiments. The usual effects that are observed when irradiating an IC devices using various sources of radiation are due in essence to three types of morphological changes in IC active layers: total ionization dose effects (TID), lattice displacement and high Linear-Energy-Transfer events (LET). The latter were only recently beginning to be considered as in general the large LET values are extremely improbable compared with other particle - e.g. minimal interacting particles or close. Yet, the studies showed a very high correlation between LET value and the cross-sections for two single event effects (SEE): single event latch-up (SEL) and single event upset (SEU), which might offset the low probability. Hence ideally all three sources of damage in IC should be carefully studied. The displacement and TID effects tend to be cumulative but as we shall show in the conclusion of this chapter the same holds true to some degree in case of SEE caused by high LET radiation.

The SEU and SEL could generate large problems by decreasing the lifetime and efficiencies of the electronics and implicitly of the sensors that the hardware serves. The SEL rates and their thresholds need to be precisely measured as the SEL events are the most damaging of SEEs due to the increase in temperature, consumed power, and the current jumps that could lead indirectly to gate rapture or burn-out of device under test (DUT). Here we concentrate on the testing of the proposed commercial off-the-shelf (COTS) solution for the PDMDB FPGA: Kintex-7 [1] which is currently under consideration. The main objective is to test the device under various radiation conditions and extrapolate the measured values to the expected LHC environment in the upgrade phase.

Kintex-7 (Xilinx) FPGA family is implemented in 28 nm HKMG - High K Metal Gate - technology featuring devices with high-density logic and signal processing capability at maximum power efficiency. This new class of FPGAs, developed for a wide range of applications, tends to be used also in avionics and high energy physics detectors. Radiation hardness tests were done to study the tolerance of these SRAM based FPGA family in hostile environments with radiation, but many issues remain unanswered like how much the radiation hardness properties change within the same generation of IC, and how does the error mitigation help solve at least some of the already observed problems.

Using a COTS FPGA and an SRAM type device is advantageous due to flexibility and low price compared with the anti-fuse solutions. The increased resources allow also to consider fundamental changes in firmware at a later stage of the Upgrade phase. Though the anti-fuse is less prone to the radiation damage effects, there is hope that the error mitigation will be sufficient to offset this difference and also reduce the power dissipation due to effects induced by radiation damage.

In this chapter we propose to cover the first measurements an LHCb-RICH group has done on a Kintex-7 device with the observation that we concentrate on the low end price-spectrum of the Kintex-7 IC, i. e. the XC7K70T dice with 1FBG484C package. It was preferred the XC7K70T version to XC7K160T as the dices are expected to be equivalent safe a difference in number of I/O pins and the relative number of resources, which should not induce a distinction with respect to radiation hardness properties at bit level. For this packing there is no lid, and since the chip is flipped, more than half of our reserve samples of 9 IC units were thinned with the initial 250 micrometer layer being reduced to 30-60 micrometers thick silicon layer on top of the active layer. This allows to test with ion beams at few hundreds MeV, which now meet the conditions to penetrate and deposit energy in the active layers.

In the next sections of this chapter we shall discuss: 1. the proposed test bench choice and. the test firmware; 2. a first set of results - the chip operation was studied in ion beams for a wide range of LET values -; 3. the preliminary conclusions and the future plans;

2 Test Bench for radiation hardness studies and test firmware

An automatic test bench was implemented and used to gather data during irradiation procedure. The device under test XC7K70T-1FBG484C, from now on DUT, was tinned down to less than 60 micrometers for heavy ions irradiation. On DUT board there are several passive electronic components which allow the FPGA basic running condition but there is no external configuration flash due to the testing constrains that were imposed by TDR choice The device of choice to power for DUT is a micro power management unit designed around ADP5050 IC along with a custom data acquisition system capable of monitoring the power usage on 4 FPGA supply rails. Overcoming the voltage drop on the cables linking the power supply unit and the DUT board was possible by placing each supply rail feedback point close to the FPGA. The DUT is configured through a Xilinx JTAG programmer and the signal generated by user defined logic is readout by a commercial FPGA board, NEXYS3. The entire test bench is controlled from a PC and it is schematically represented in figure 1. Two LabVIEW graphical user interface tools were developed to control the setup, display data and write them in ASCII files for later analysis. Screen captures of these two are presented in figures 2.

Multiple versions of firmware were developed to evaluate specific FPGA resources under irradiation like: Flip-Flops (FD), SLR32 shift registers, block RAM (BRAM) resources, configuration memory (CRAM). A sketch of the firmware architecture is given in figure 3. The Software error mitigation LogicCore controller or simply the SEM IP Core is an embedded controller in the DUT firmware design which does configuration-memory scrubbing. A triple modular redundancy (TMR) is generally used for the user defined logic which was design to implement an aggressive error mitigation scheme. This was required in the follow-up of the first ion beam test when we observed a the high rate of SEU in the essential device configuration-memory. As will appear evident in the conclusion of this chapter the error mitigation methods were enough to considerably improve the logic survival and also protect the circuit itself from the large SEU effects by decreasing to close-null value the probability to have avalanche in the activation of FPGA configuration in the wake of multiple- SEU with cumulative effects.