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The LHC program and the CMS upgrade. After the discovery of the Higgs boson in 2012, based on RunI data, LHC, the 13-14 TeV pp CERN collider, has run in 2015-2018 (RunII). The RunIII is scheduled for 2022-2024 before the long shutdown planned for 2025-2027 when LHC will be upgraded to reach an unprecedented instantaneous luminosity of about $10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, a factor five increase with respect to the current figures. The High Luminosity program (HL-LHC) will start in 2027 and will allow CMS (Compact Muon Solenoid), one of the general-purpose experiment at the LHC, to collect $\sim 4000\mathrm{fb}^{-1}$ of integrated luminosity over a decade.

In order to cope with the much higher pp-collisions rate, CMS will undergo an extensive improvement known as "Phase-2 upgrade": in particular the silicon tracker system will be entirely replaced [1] to comply with the extremely challenging experimental conditions. The new system requirements, with respect to the current tracking device, are: higher granularity; extended geometrical acceptance; larger read-out bandwidth; trigger capabilities; higher radiation tolerance.

The HL-LHC CMS physics program aims to measure Higgs boson's properties with better precision, explore possible physics signals beyond SM and search for anomalies in well known processes.

Study of Lepton Flavour Violation in B-decay in CMS. A recent measurement of the Lepton Flavor Violation (LFV) from the LHCb collaboration [2] has shown a 3.1σ discrepancy with respect to the Standard Model prediction. The study relies on B-meson semi-leptonic decays and compares the branching fractions corresponding to different lepton flavors in the final state. If confirmed, this result would imply physics beyond the Standard Model, such as a new fundamental interaction between quarks and leptons.

In 2018 CMS collected a special data sample containing about 10^{10} B candidates selected by a dedicated trigger stream, the so called "B-parking" dataset, to be used for B-physics analyses based on low momentum tracks. Such B-physics studies would have been impossible with the standard trigger strategy of CMS given the high transverse momentum thresholds needed to keep event rates at acceptable levels. On the contrary, to avoid a large impact on the CMS computing resources, the events of the B-parking dataset are not reconstructed promptly but in an opportunistic way when CPU-time is available (e.g. during shutdown periods).

I propose to exploit the B-parking dataset for a LFV study based on the measurement of $\mathcal{R}(D^\star)$, which is the ratio between branching fractions of B meson decaying in excited D meson and a muon or tau lepton pair, i.e. $\mathcal{R}(D^\star) = \mathcal{BR}(B_0 \to D^*\tau\nu_\tau)/\mathcal{BR}(B_0 \to D^*\mu\nu_\mu)$. $\mathcal{R}(D^\star)$ could reveal lepton flavour universality violations effects. This measurement strongly relies on the primary and secondary vertices reconstruction and on the accurate measurement of charged particles transverse momentum in the tracker. In particular, to select and identify B mesons, special "b-tagging" algorithms which strongly depend on the tracking devices are crucial. I will use state-of-the-art Machine Learning techniques to fully exploit the excellent performance of the CMS Tracker for the efficient discrimination of prompt muons coming from direct B decays from the secondary muons coming from the τ decays.

It comes clear from the above discussion that LFV analyses relies on three crucial aspects: magnitude of data samples, i.e. integrated luminosity, since tiny effects are under study; trigger strategies, since relatively soft tracks from B-meson decays are involved; tracking capabilities, since b-tagging techniques and transverse momentum resolution are of paramount importance in this kind of analyses. All these aspects will profit from a significant boost within the HL-LHC program and the CMS Phase-2 upgrade, giving a unique opportunity to address the LFV analyses with an unprecedented horizon. I will extrapolate the techniques developed to target LFV studies within RunII data to the HL-LHC scenario by means of Monte Carlo simulations. In particular I will focus on the impact of the future tracking system on the CMS sensitivity to LFV effects.

As a further step in this direction and to deeply understand the instrumental effects of the detector that will be crucial for this physics result, I will contribute to the ongoing future tracker project, performing studies on new pixel sensors and read-out electronics.

Consolidation of 3D silicon pixels sensors devices and service electronics for the CMS upgrade. Frontier technologies are required for the CMS detector upgrade and the pixel sensors makes no exception. Two pixel sensor technologies are being evaluated to instrument the Inner Tracker of the upgraded CMS: planar sensors and 3D sensors, both of 150μm active thickness [3]. The latter differ from the more common planar ones for the geometry of the implants. In the planar detectors the junction electrodes are located on the surface while in the 3D detectors the electrode implants are columnar and penetrate deep into the silicon bulk for almost the full thickness. In the standard 3D design a rectangular pixel cell is made up by a central n^+ column and four p^+ columns at the corners. In such a configuration the mean path of the electrons and holes generated by the charged particle ionization is shorter than in the planar case, reducing the trapping probability due to the defects induced in the bulk by the irradiation. This makes 3D sensors intrinsically radiation tolerant.

The sensors read-out is currently performed with the RD53A [4], a read-out chip (ROC) prototype jointly designed by the ATLAS and the CMS collaborations which features all the cutting-edge technology requirements needed by the Phase-2 upgrade: low threshold, low power consumption with serial powering capabilities and large readout bandwidth. The extensive testing activities carried out on the RD53A culminated in the design of the CMS Read-Out Chip (C-ROC) whose prototype has been just recently submitted for fabrication. This new ROC has the final size, about twice in area with respect to RD53A, and will be tested in 2022 in Florence for the first time ever as a part of this project.

A crucial aspect of the Inner Tracker is the powering scheme. In fact, for the first time in a large-scale high energy physics experiment, a serial powering (SP) approach has been chosen in order to minimize the passive material of the cables which feed the 50kW power needed to operate the Inner Tracker. Alternative, more traditional, powering approaches would spoil the excellent physics performances due to material effects. In the SP scheme a single power line serves a chain of up to 8 modules in series. This new SP approach requires a detailed knowledge of the behaviour of the system and hence extensive testing activities are foreseen on realistic, full-scale, bench systems.

Within this project a full system corresponding to a SP chain of CROC-based pixel modules will be set-up in order to gain operational experience and to assess the performance and the reliability of the final system. Hence, pixel-sensor modules arranged in the final configuration by means of all ancillary electronics will be characterised through laboratory tests and in tests on beam at appropriate facilities such as CERN SPS or DESY. In the laboratory it is possible to run and optimise calibration procedures and to test the read-out by using beta or x-ray sources.Whereas at Test Beam facilities, where a particles beam is present, it is possible to study quantitatively the detector's hit reconstruction efficiency and the spatial resolution. As a part of the project I will perform both laboratory and on-beam tests.

[1] CMS Collaboration, *The Phase-2 upgrade of the CMS tracker*, 09-2017. CERN-LHCC-2017-09; CMS-TDR-014.

[2] LHCb Collaboration, *Test of lepton universality in beauty-quark decays*, arXiv:2103.11769.

[3] M.Meschini et al, *Radiation resistant innovative 3D pixel sensors for the CMS upgrade at the High Luminosity LHC*, NIM A (978) 10-2020. https://doi.org/10.1016/j.nima.2020.164429

[4] M. Garcia-Sciveres, *The RD53A Integrated Circuit*, CERN-RD53-PUB-17-001 (2017).