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PhD position

The "Laboratoire de l'Accélérateur Linéaire" (LAL) in Paris-France region invites applications for a PhD student with the title

Participation in the construction of the ATLAS tracker in view of the high-luminosity Phase-2 upgrade. – Measurement of the Quartic Gauge Couplings in Vector Boson Scattering with ATLAS detector, using the full LHC Run-2 Dataset.

The ATLAS group of LAL has made significant contributions to the construction and operation of the experiment. It is presently contributing to event reconstruction (electrons, jets), Higgs studies, searches for new physics, SM precisions measurements, as well as the High Luminosity (HL)-LHC upgrade, with activities in the upgrades of the tracker and the high granular timing detector.

The selected candidate will work on two main topics

- Hardware: participation in the construction of the ATLAS tracker in view of the HL-LHC upgrade.
- Physics analysis: measurement of the Quartic Gauge Coupling in Vector Boson Scattering with ATLAS detector using the full LHC Run-2 data (120-150 fb^{-1}).

The post has duration of 3 years with a nominal starting date in September 2018, with a possibility to start up to 6 months earlier, prior to joining the PhD programme officially. The doctoral requirements include research studies leading to the preparation and defense of a thesis, as well as a number of publications. The post provides financial support for the full duration.

Interested candidates should have (or soon receive) the equivalent of a Master degree with a specialization in Particle Physics or related activities as well as outstanding grades. To apply please send a CV, grades record, a motivation statement and up to three reference letters to Dimitris.Varouchas@cern.ch . Applications should be sent by **22 December.**

If necessary, you can find details on the topic in the following pages

Hardware

The actual ATLAS Inner Tracker is compatible with the LHC design luminosity of 10^{34} cm^{-2} s^{-1}. The foreseen increase towards High Luminosity (HL) LHC phase (Phase-2 upgrades) with peak luminosities of up to $8\text{-}10\times10^{34}$ cm^{-2} s^{-1} requires a fundamental re-design of the complete inner detector due to both, increased radiation damage, and substantial occupancy of the sub-detectors. The R&D of this new fully silicon based tracker (ITk) is currently at the final stage and the last Technical Design Report is expected by early 2018. Right after that, the important phase of the pre-production will start until middle of 2020, and the actual production and loading will start right after, with a timeframe of 2-3 years.

The ATLAS group of LAL, after having participated successfully in the R&D phase, is now ready to take the responsibility of constructing a part of this detector based on planar pixel sensors, which is the expertise of the group. The PhD candidate will take part of the production project following the timeline of the ITk. Activities of the candidate will include several tasks, from sensor and module electrical and thermal characterizations in clean room in collaboration with the LAL engineers and technicians, to the qualification of the final modules in beam tests at CERN and DESY laboratories, before and after irradiation. In particular for the latter, part of the work will be the optimization of the tracking reconstruction algorithms in order to improve the test beam analysis. Given the current ITk construction schedule, the PhD student will have the chance to participate in the characterization of the final pixel ITk modules with the readout cheap that is expected in early 2020.

Physics Analysis

The non-Abelian nature of the Standard Model (SM) that is based on the symmetry $SU(3)_C \times SU(2)_L \times U(1)_Y$, predicts the existence of Quartic Gauge Couplings (QGC) that opens a window to study the details of the Electroweak Symmetry Breaking (EWSB) mechanism. Moreover, thanks to the Higgs boson and its specific couplings to the vector bosons the $W_LW_L \rightarrow W_LW_L$ cross section does not violate unitarity at about 1 TeV. Thus, measuring the QGC in Vector Boson Scattering (VBS) is considered a unique independent test of the SM nature of the Higgs boson. VBS results into topologies with two vector bosons (only Ws will be considered for this thesis) of same sign and two jets produced at the forward region of the detector. This is a very rare process in the SM and it hasn't been observed yet in ATLAS. It is expected that with the current, on-going measurement of the 2015&2016 LHC dataset (~40 fb^{-1}) a ~5σ observation of this topology will be achieved, similar to the CMS result published recently. The thesis work will start at the fall of 2018, a few months before the completion of LHC Run-2 and the start of another LHC long shutdown that will last until 2021. This is therefore the ideal timeline for a precise SM measurement using the full Run-2 dataset (expected to be 120-150 fb^{-1}) aligned with the ATLAS publication plan for the Run-2 analyses as presented to the collaboration recently.

Forward jet performance is of paramount importance in this analysis. The thesis work will start with a detailed study of optimizing the jet reconstruction, in particular developing novel techniques towards mitigating the pileup jets in the forward region. This will be achieved by combining information from the tracker and the calorimeter that is balancing with jets in the forward region of the detector. This is an approach that is promising and currently poorly

exploited. The student is expect to get involved quickly with the analysis so that he/she will master all the tools and experimental aspects as quickly as possible; the first contributions to the analysis are expected though the forward jet reconstruction optimization.

Assuming that time and LHC data statistics permit, the analysis can be extended by performing differential cross section measurements. The QGC can be measured as a function of several observables in particular the polarization of the W bosons. This measurement is one of the most important milestones of ATLAS physics programme, because of its strong connection to the mechanism of EWSB.

Team Description

Dimitris Varouchas will supervise the thesis in both the hardware and the physics analysis parts.

- ITk construction (pixel hardware)

The team consists currently of Abdenour Lounis, Dimitris Varouchas with contributions from Rei Tanaka, Claire Bourdarios and Lydia Fayard and several LAL engineers and technicians. Dmytro Hohov is currently the PhD student of the group and will be starting the 3rd year by the time of the PhD candidate will start the thesis. This team exists since 2006 and has had numerous contributions in the ATLAS IBL Pixel design and construction, as well as in the R&D of silicon detectors focusing on the active-edge pixel sensors, a crucial element of ITk. The team has currently a vital role in the construction of the ITk pixel detector having taken the responsibility of constructing a part of it, in collaboration with the Paris region labs of LPNHE and Saclay-IRFU.

- Vector Boson Scattering measurement (physics analysis)

This is a newly formed team within the ATLAS group of LAL. Dimitris Varouchas is the main actor. Lydia Fayard will follow the activities and Nikola Makovec (jet expert), Laurent Serin (HGTD responsible in ATLAS) and Zhiqing Zhang (dibosons expert) have expressed interest in following the developments of this analysis. The Vector Boson Scattering with its characteristic topology of two vector bosons produced centrally in the detector and two jets produced in the forward regions of the detector, depends significantly on the forward jet performance, in which the HGTD is expected to play a crucial role in the future. Dimitris Varouchas and Nikola Makovec have been jet reconstruction conveners in ATLAS over the past years and their expertise will be indispensible in leading this analysis. This activity could make part of a bigger effort -having started in ATLAS-LAL group since a few years now- within the frame of precision measurements in the electroweak sector (notably the measurement of the W boson mass).