STUDY OF A HIGH GRANULARITY AND HIGH PRECISION TIMING DETECTOR FOR THE LHC AT HIGH LUMINOSITY BASED ON THE MICROMEGAS TECHNOLOGY. APPLICATION TO THE MITIGATION OF THE COLLISIONS PILE-UP EFFECTS IN THE PHYSICS ANALYSES WITH THE ATLAS DETECTOR.

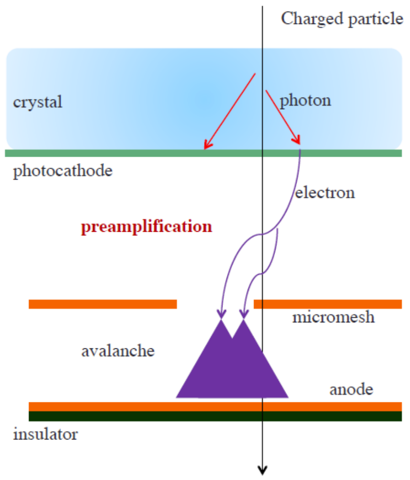
DESCRIPTION ET PROBLEMATIQUE

After the discovery of the Higgs boson with run1 data at 7 and 8 TeV energy in the centre of mass of the proton-proton collision, the major goal of the LHC is to look for possible signals of physics beyond the Standard Model, either by a precise analysis of the properties of the Higgs (in particular its coupling with other particles) or by direct searches of final states not explainable within the Standard Model. In addition to the rise in energy at 14 to 13 TeV, this research will demand a drastic increase in luminosity of the collider. From 2025 onward (HL-LHC phase), it is planned to operate the LHC with more than 200 collisions per crossing of protons bunches, which will greatly complicate the analysis, particularly in the forward regions, where it will be very difficult to link the tracks with the primary vertex (associated with the only interesting collision) and thus to prevent the formation of fake jets created by the random stacking or pile-up of tracks from several secondary vertices.

A solution proposed to fight against this pile-up effect in the forward regions (pseudo-rapidity greater than 2.4) is to measure very accurately the time of arrival of the particles just before they enter the endcap calorimeter to reject by the time of flight technique those associated with secondary vertices spread longitudinally over a distance of about 20 cm at the centre of the detector. A time resolution of a few tens of ps with a spatial granularity better than 1 mm will be needed to obtain a fake jet rejection rate that is acceptable for physics analyses. Such performances should be obtained with a detector capable of withstanding the very important radiation levels expected in this part of the detector. Current techniques that would allow such performances like avalanche diodes would not withstand this level of radiation.

In this thesis, we will study a detector based on the combination of a crystal to generate Cherenkov radiation, a photocathode and a gaseous detector based on the MicroMegas technology with a short drift space to identify and measure precisely the arrival time of the photoelectrons. Other secondary electron emission devices may also be considered.

The candidate will also study the impact of such a detector on the rejection of fake jets in the forward regions and the measurement of the missing transverse energy using detailed simulations of collisions in the ATLAS detector in its configuration expected for the HL-LHC. Such a timing detector could also help in the search for "exotic" massive particles traveling at a speed significantly lower than the speed of light.



Principle diagram of a timing detector based on a MicroMegas chamber with small drift space (~200 µm) turned into a preamplification gap.

DESCRIPTION

GROUPE/LABO/ENCADREMENT

The student will work both with physicists from the Particle Physics Service (SPP) of the IRFU, mainly on simulation issues of pile-up background rejection, as well as with engineers from the Service d'Électronique des Détecteurs et d'Informatique (SEDI) for most aspects related to the development of sensors. As the choice of technique for this timing detector will not happen before mid-2017 within the ATLAS collaboration, the candidate will be required to make presentations at CERN to present the results of his studies to convince the collaboration if the results are positive. If this technique proves to be successful regarding the performances and the technical and financial aspects, the candidate will participate in the preliminary study of the final detector under the supervision of the project manager (SEDI) and the chief scientist (SPP).

TRAVAIL PROPOSE

The student will begin working with the small prototype (size of the order of one cm^2) already existing in SEDI aiming at the optimization of different parameters such as the nature of the gas in the MicroMegas chamber, its geometry, the nature of the device creating the secondary electrons (Cherenkov crystal, photocathode, or another device emitting many secondary electrons such as a diamond crystal with a special surface coating). These studies combine a simulation of the detector components including all the physical phenomena which occur till the electric signal production as well as experimental tests, either with a pulsed picosecond laser or with test beam from an accelerator at CERN. Studies of resistance to radiation from intense sources of neutrons or photons are also planned.

Another component of the work is to study the impact of such high granularity timing detector on the rejection rate of fake jets in the forward regions, on the measurement of the transverse missing energy, and on the rejection of background noise in certain physical channels analysed at the HL-LHC. The working tool is the ATLAS simulation program in which the timing detector must be integrated.

FORMATION ET COMPETENCES REQUISES

Master2 in particle physics and / or instrumentation for physics. A pronounced taste for laboratory experimentation is required.

COMPETENCES ACQUISES

With the two complementary parts of this thesis, the student will acquire multiple skills covering:

- The design, construction and testing of detectors and electronic circuits.
- The knowledge of the GEANT simulation software.
- Learning programing languages C++, python...
- Statistical analysis of the data and a first approach of data analysis at the LHC.

COLLABORATIONS/PARTENARIATS

The thesis will include frequent missions to CERN (meetings, beam tests).

There may also have an involvement in the design and the construction of the final detector requiring contacts with industrial partners.

CONTACTS

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