# Report on PhD activities

Second year

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Roberto Mulargia - roberto.mulargia@ge.infn.it

*supervisors*: Enrico Robutti *and* Silvano Tosi.

Università di Genova *and* Istituto Nazionale di Fisica Nucleare - Sezione di Genova



***Abstract*—In this report I will describe my studies and work during last year. The classes I attended and the teaching assistance activity are detailed first. Then the research activity is briefly described, mainly focused on data analysis at the CMS experiment at CERN, along with experimental studies on innovative silicon timing detectors.**


## I. Classes and T.A.

- Collider Physics
- Particle Detectors
- Electronics and Data Aquisition
- Gravitational Waves
- Statistics and Probability (exam in coming weeks)
- *approved school*: CMS Data Analysis School

Tutor for the class *Fisica Generale* of the *Corso di Laurea Triennale in Scienze dei Materiali*.

## II. Central Exclusive Production of top-antitop quark pair

The goal of the analysis is to estimate the cross section of the Central Exclusive Production (CEP) of a $t\bar{t}$ pair, as described by the diagram in Fig.3, using data from the Compact Muon Solenoid (CMS) experiment at CERN. The main characteristic of this process is a correlation between the kinematics of the $t\bar{t}$ pair and that of the two protons which survived the collision.

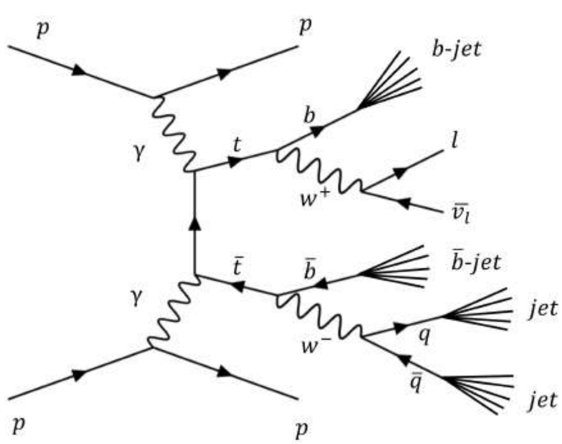
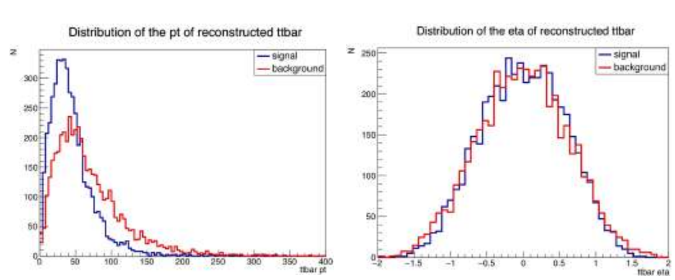



Figure 1: Feynman diagram for the $t\bar{t}$ CEP process

The current work deals with the reconstruction of the top-antitop pair: in particular through its *semi-leptonic* decay channel where the $W$ boson coming from the decay of one top decays in a lepton-neutrino pair and the other $W$ decays in quarks and hence appears as two light jets.
Simulated data (Monte Carlo) containing signal or background events is being analysed, before turning on for real data. The main background is expected to be the production of $t\bar{t}$ pairs by any other already known process. In order to select the signal and reject the background it is necessary to study the signal characteristics which differentiate it from the background. The distributions of some variables have been already produced and some of them show encouraging differences between signal and background (Fig.2a) while others do not (Fig.2b). This work is a necessary pre-processing of data, also referred to as feature extraction or variable selection, which is the starting point for a more refined Multivariate Analysis (MVA). Currently each event is characterised by a set of values for each of the $n$ kinematics variables which define it, same as the $n$ components of a vector in a $n$-dimensional feature space. Setting thresholds for some variables based on a process of trial and error informed by common sense and physics insight is often referred to as "cut-based" selection in HEP. This selection results in "rectangular" cuts in the feature space and there is no guarantee that this will lead to optimal cuts.
The Multivariate Analysis makes use of advanced machine learning technologies in order to reduce the dimensions of the feature space and find the optimal selection.




(a) (b)

Figure 2: Comparison between signal and background.

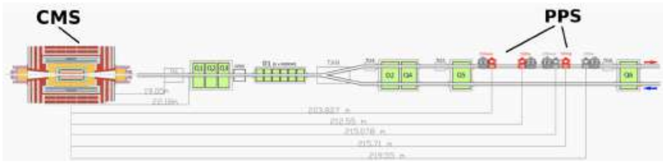



Figure 3: Schematic description of the PPS detectors.

## III. Pixel Tracking Detector for CMS Precision Proton Spectrometer

The *Precision Proton Spectrometer* is a detector, fully integrated in the CMS experiment, whose focus is the measurement of the protons which survive intact an interaction in the fifth LHC interaction point (IP5) where CMS is located. In order to do so it is installed about 200 $m$ on both sides from IP5 and consists in 4 tracker stations 3D silicon pixel sensors and 2 timing stations.
The tracking detector allows the measurement of the relative momentum loss of the surviving proton $\xi = \Delta p/p$ which is related to the energy available in the central system, while the timing mitigates the pile-up, which is the effect of multiple proton proton interactions in any given bunch crossing in the LHC

The current work involves the redesign of the pixel tracker which will be ready for data taking during LHC Run 3 (2021-2023). The main characteristics of the new detector will be:

- new 3D silicon sensor production;
- updated readout (ROC) and token bit manager (TBM) chips;
- redesigned front end electronics;
- new support structure allowing a remotely controlled lateral movement;
- updated data acquisition (DAQ) system.

Irradiation studies on the new ROC and the design of the new structure have been already done in Genova.

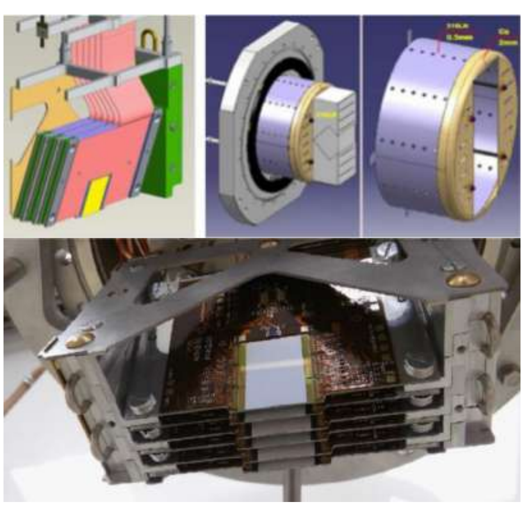
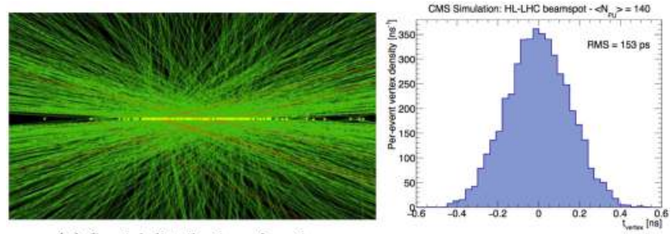


Figure 4: The pixel tracker for the PPS detector.




**(a)** Spatial distribution of vertices

**(b)** Time distribution of vertices

Figure 5: Expected pile-up conditions in HL-LHC

## IV. Development of fast electronics for timing detectors

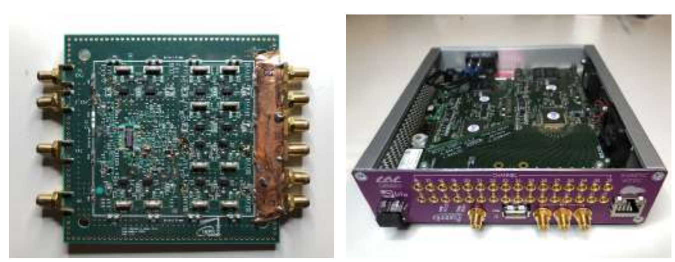
As the LHC experiments prepare for the upgrade of LHC known as High-Luminosity LHC, assigning a time information to the tracks will be a crucial tool against the extreme pileup conditions which are expected (Fig.5). CMS is planning to do so by building an apposite *MIP Timing Detector* (MTD) and the Genova group is involved in the R&D studies for timing sensor technology.

### A. *Analog readout board*

A six channel, broad band, analog amplifier board (Fig.6a) has been designed specifically for silicon timing sensors. The current work consists on extensive studies of its performances with LGAD and silicon 3D timing sensors in laser and particle beam tests.

### B. *SAMPIC*

The *SAMpler for PICosecond time pick-off* is a readout chip for fast timing detectors provided by IRFU/SEDI Saclay and in LAL-Orsay as a ready -to-use system (Fig.6b). The SAMPIC approach to timing is to acquire the full waveform shape of a sensor signal in a dedicated ASIC. The main activity on this system consisted in acquiring experience with its functioning in view of a likely future importance of this systems in HEP.



(a) Amplifier board

(b) SAMPIC

Figure 6: Timing electronics under R&D.

## V. Talks and publications

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|---|---|
| poster | Search for CEP of ttbar @CMSweek(Oct2018) |
| talk | Endcap Timing Layer @CMSItalia(Nov2018) |