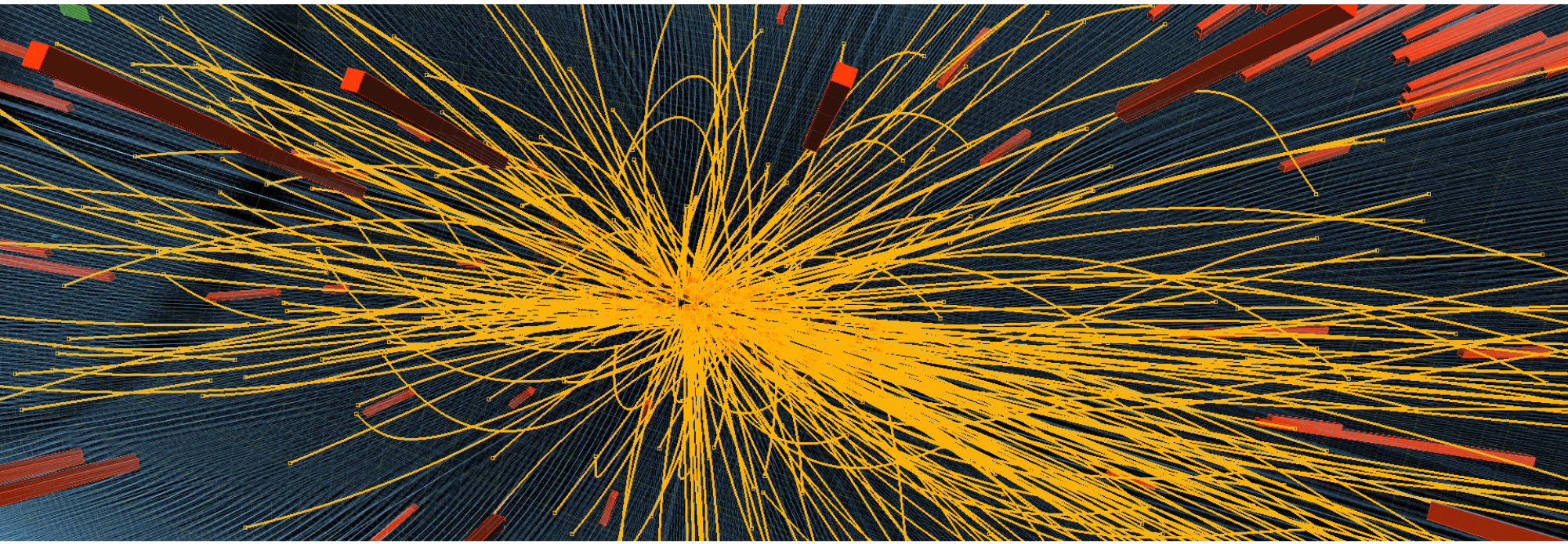
# Higgs Boson Properties With CMS Experiment

## Working Package 1: Interpretation of data



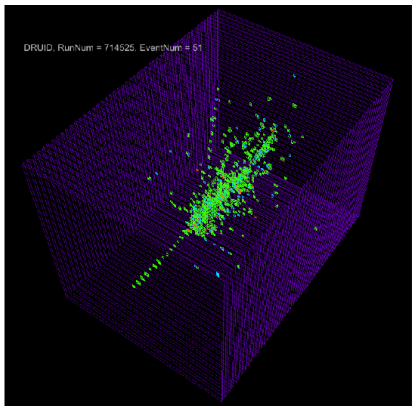
Yacine Haddad (ESR 4), Supervisors: N. Glover (UDUR), G. Davies (ICL)
IPPP, Durham University

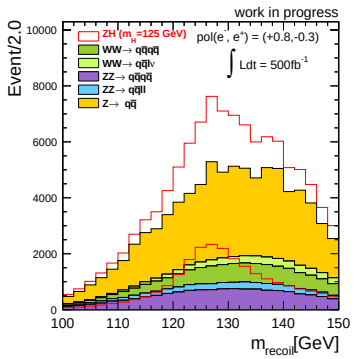
October 20, 2015

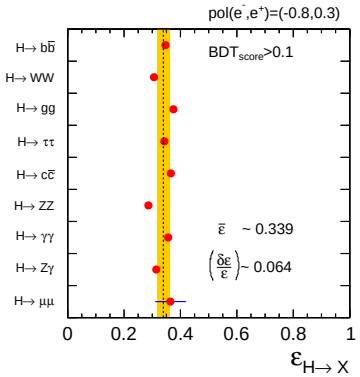
# Introduction

## Background

- Born in Algeria, where I did half of my Education: graduated in theoretical physics (2009). Then I went in France for Master degree (graduated 2011) and for the PhD.
- PhD Thesis with ILC-CALICE group, École polytechnique, France
  Title: Highly granular semi-digital hadron calorimeter of future $e^+e^-$ lepton collider and model independent measurement of the Higgs boson in the hadronic channel $\mathrm{ZH} \to q\bar{q} + \mathrm{X}$
- Achievements :
  - Development of Monte-Carlo simulation, Calibration and Characterisation for SDHCAL prototype
  - Demonstration of a model independent measurement of the Higgs boson using the recoiling jets from the Higgs-strahlung production mode.
- Outcomes:
  - 4 papers as first author + active contributions to 4 other papers + co-author of 7 publications with CALICE Collaboration
  - Finalisation and publication of the thesis on February 12th, 2015



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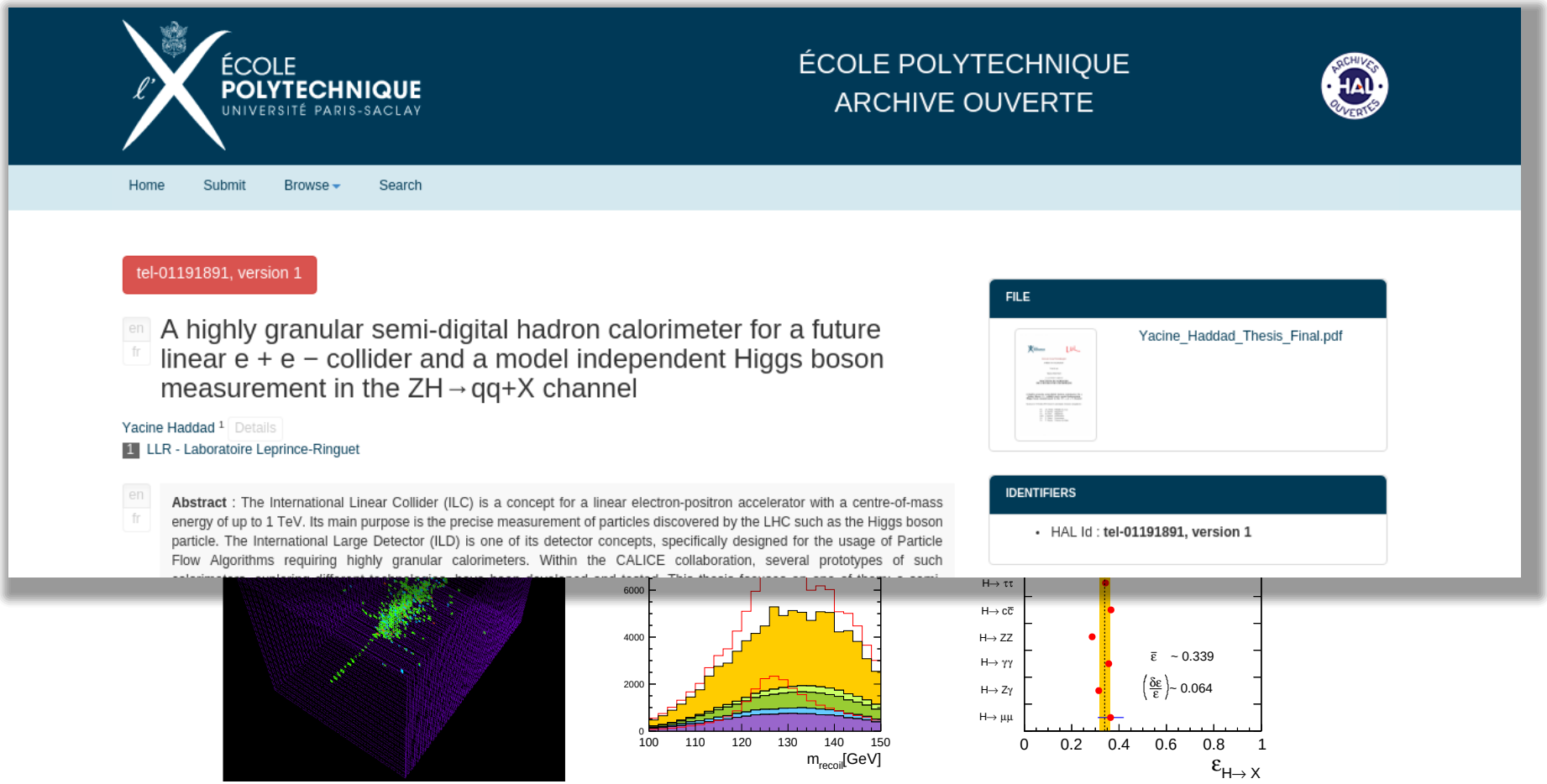


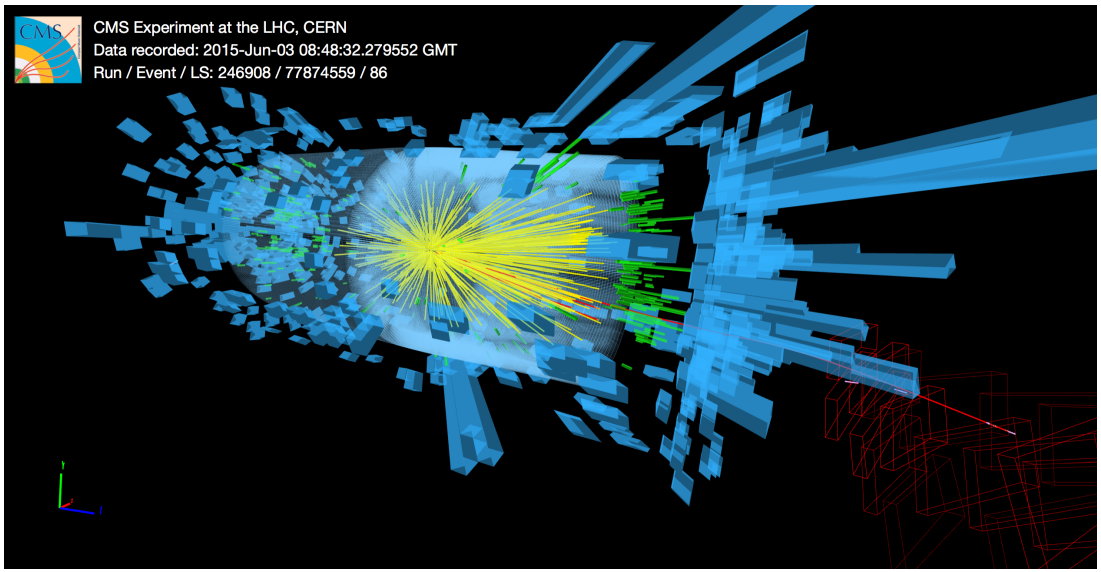
My project focuses on the measurement of the Higgs properties with CMS experiment within Durham University and Imperial College London.

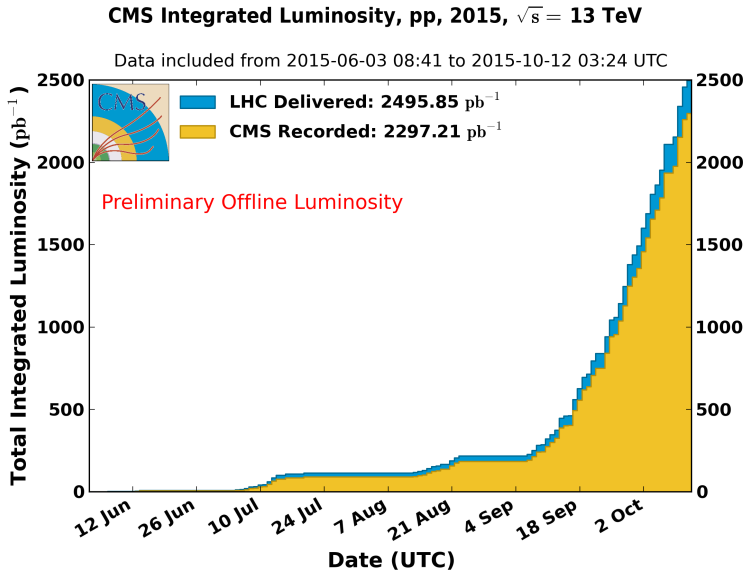
- Supervisors: **Nigel Glover** (IPPP Durham), **Paul Dauncey / Gavin Davies** (Imperial College London)
- Started 01/11/2014

**The main goals are:**

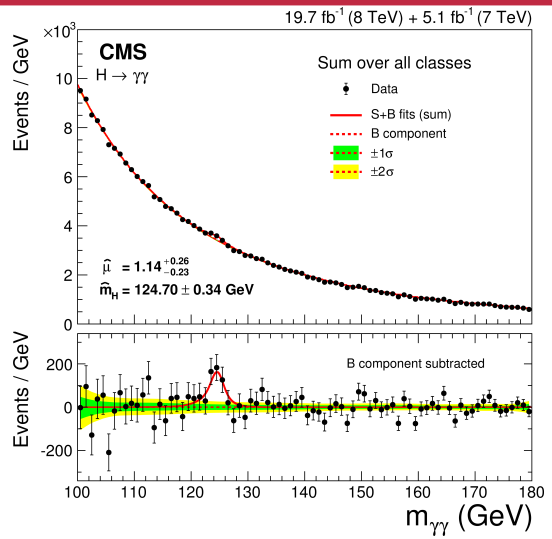
- Exploitation of the LHC-Run II data:
  - Development & validation of the $H \to \gamma\gamma$ analysis framework
  - Re-discovering the Higgs boson with $13$ TeV data
- Studying and understanding QCD jet production, with aim of improving the Higgs boson sensitivity mainly in the Vector Boson Fusion (VBF) production mechanism (with $H \to \gamma\gamma$).
- Measurement of the Higgs Properties (Spin/CP, couplings, self-coupling, ...) with the LHC-Run II data

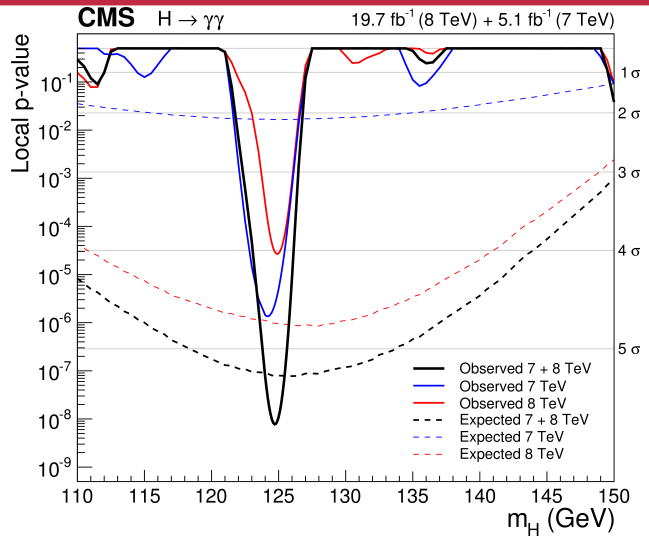
- Since June 2015, the LHC delivers pp collision at 13 TeV
- So far CMS recoreded about $2.2\mathrm{fb}^{-1}$, still increasing
- This marks a new energy frontier in particle physics



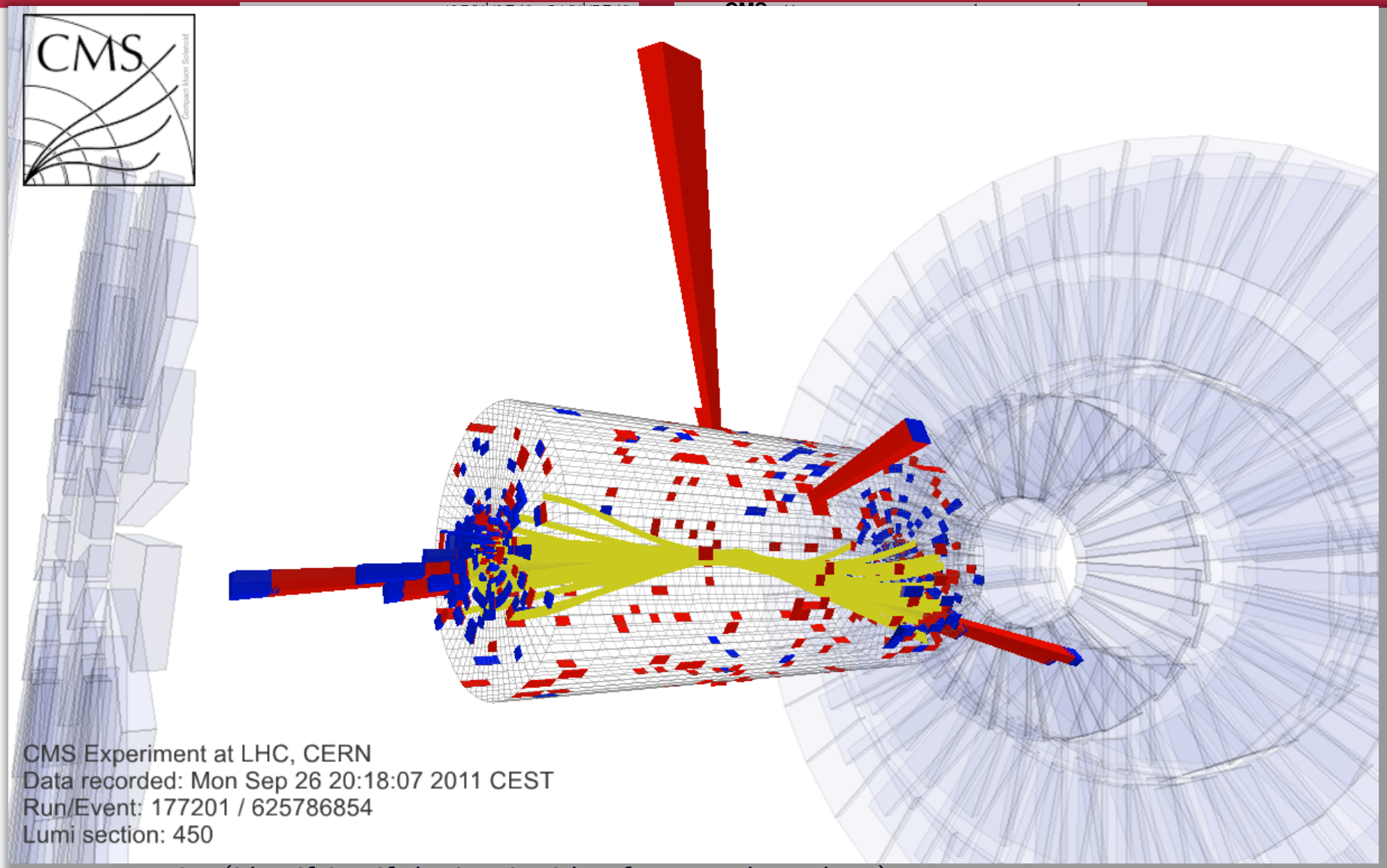




- What to do with these data ?




- Reminder: The Higgs boson was discovered in 2012 by ATLAS and CMS collaborations at LHC
- One of the main channels is the $H \to \gamma\gamma$: clean signature, allows measurement the Higgs' properties
- The second most important Higgs boson production process at LHC is the Vector Boson Fusion (VBF)
- This production mode is characterised by
  - Very low hadronic activities in the central rapidity region
  - Two energetic **quark jets** with a large rapidity gap (from the scattered quarks)
- The good reconstruction of jets is important to increase the sensitivity of the $H \to \gamma\gamma$ analysis → It is important to reduce the pile-up contribution (next slide) to the jets and determine the jet's properties (identifying if the jets is either from quark or gluon)

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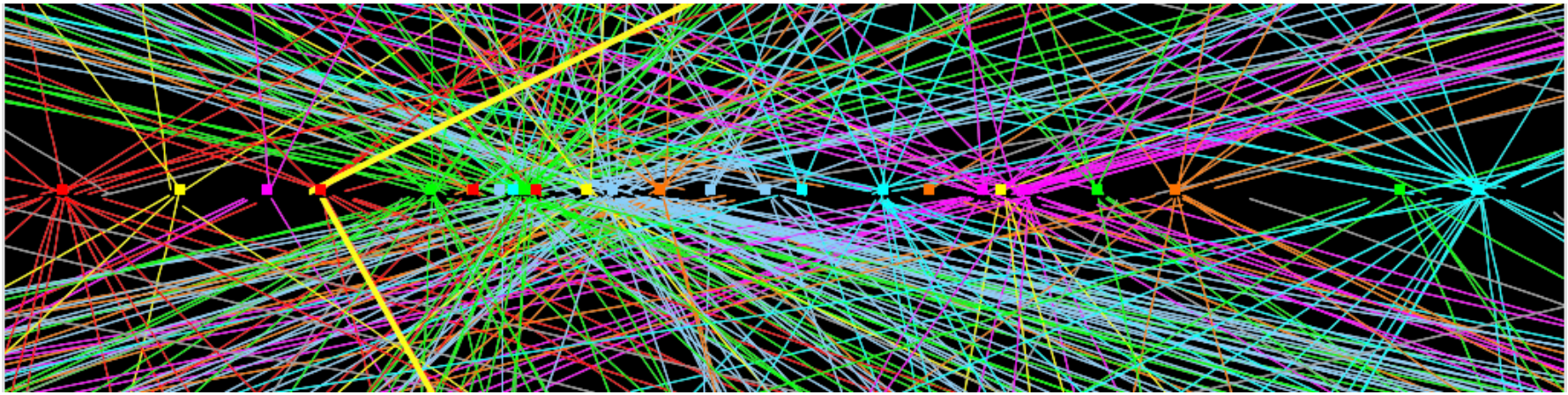
- Pile-up constitutes one of the main challenge for the analyses at the LHC



- The goal: reconstruct jets coming from the primary vertex where the hardest pp collision happened
- How might we do this ?
  - Remove the jets which are more likely composed by the tracks from pile-up
    - Track based variables. ex: $\beta^*$ : ratio of the energy carried by charged track from another primary vertex in the jet over the energy of the all the track in jet
    - Shape based variable. ex: $\langle \Delta R^2 \rangle = \sum \Delta R^2 p_t / \sum p_t$

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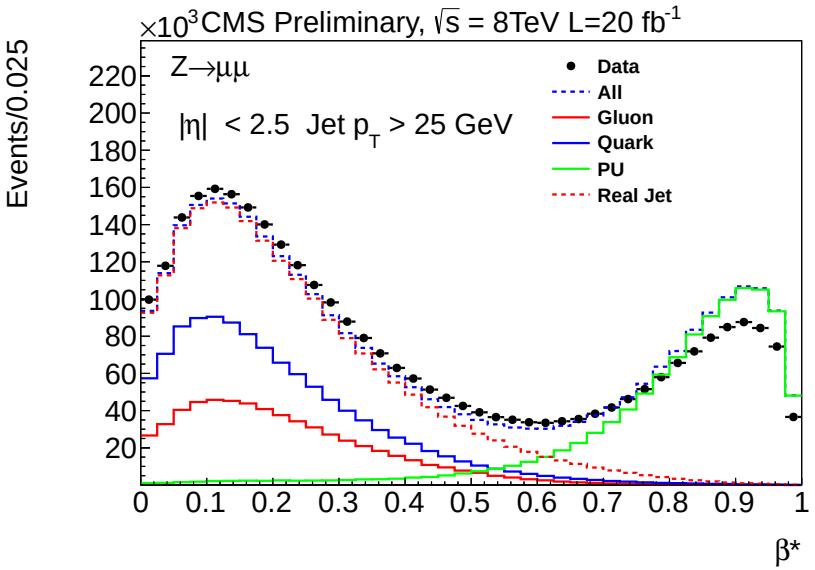


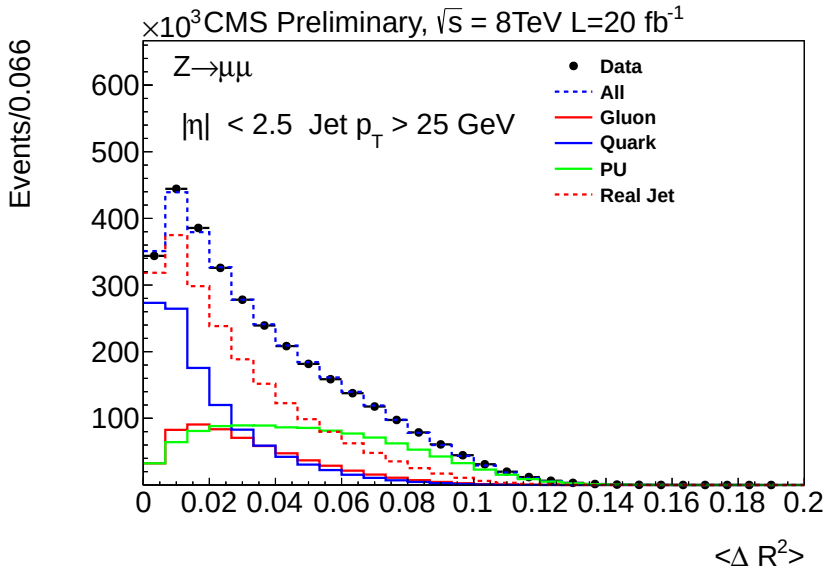

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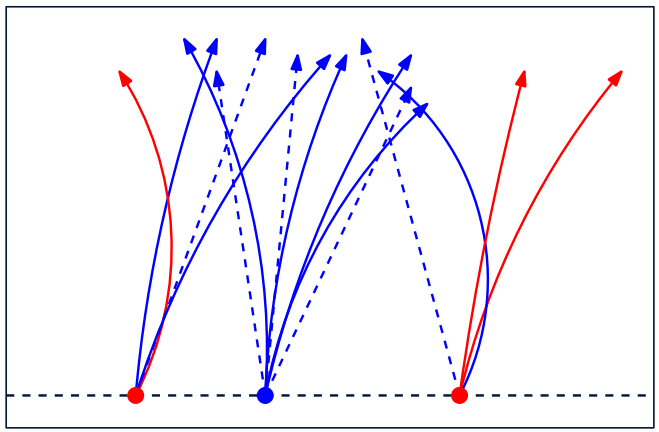

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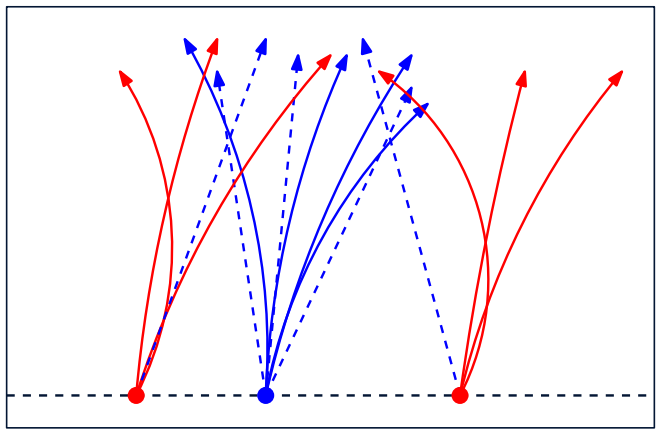

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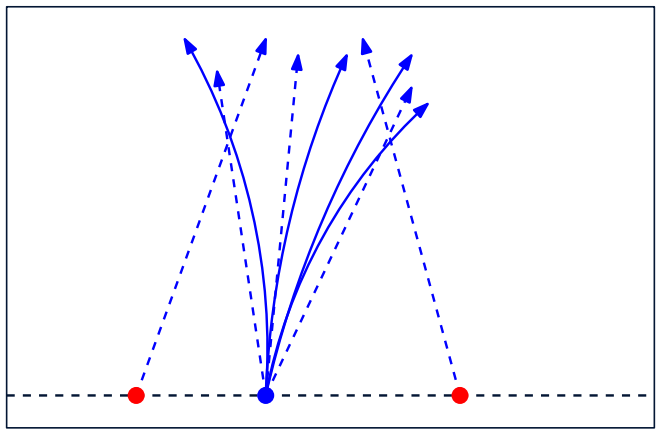

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# Conferences, Training and Publication

**Conferences**:

- 12/2014: Invited talk the third French Linear collider days (Journées Collisionneur Linéaire)
  talk : Model independent analysis for $\mathrm{HZ}(\mathrm{Z} \to q\bar{q})$ at ILC250 and FCC
- 04/2015: HiggsTools, First Annual Meeting, Freiburg, Germany
  talk : Weak Boson Fusion Higgs boson production in CMS
- 10/2015: Higgs Coupling 2015, IPPP Durham

**Training**:

- 02/2015: First Young Researchers Meeting
  Collaborative Teamwork and Communication
- 06/2015: First HiggsTools Summer School

**Secondment:**

- Academic secondment at Imperial College London (Febrary to April and June)
  - Worked more closely with ILC team
  - $\to$ Responsible of the Jet validation and VBF tagging in CMS $H \to \gamma\gamma$ analysis group

**Taking advantage of the HiggsTools netwok**:

- Within Davide Napolitano (ESR1), we organise of the HiggsTools Journal Club:
  A regalar opportunity for discussion and exchange beteen ESRs.
- Trainings and summer schools
- YRM this week, participating to VBF/MC/PDF session

**Publication**:

- CMS will validate my authorship at the end of this year (2015)

**Visits to CERN**:

- I visited CERN 2 times for 1 week period (4/2015, 5/2015), next visit will be next week (from 26 October)

# Summary

## prospectives and future plans

**Current & Short term plans:**

- Finalising the studies on the pile-up mitigation and estimate the impact on the analysis
- Implementation of Multi-Variate Analysis for tagging the VBF($H \to \gamma\gamma$) signature

**Mid term plans:**

- Writing an analysis note summarising my work on the pile-up mitigation for $H \to \gamma\gamma$
- Important deadlines ahead:
  - Producing first (preliminary) result for Moriond 2016,
  - VBF results for summer 2016 (ICHEP 2016 ... )

**Long term and Carrer plan:**

- Obtain a leading position in the $H \to \gamma\gamma$ analysis (sub-convener) in CMS
- Find a future position in a University/Laboratory which matches my interests and my passion to high energy physics
- Planning to start the private secondment with Wolframe in June 2016