LLR implication in the CMS Trigger

Alexandre Zabi for CMS LLR Group

DAS Visit to LLR

3rd Mai 2016

INTRODUCTION

Triggering on physics: The trigger plays a central role in selecting the interesting events we need to carry out our ambitious physics program.

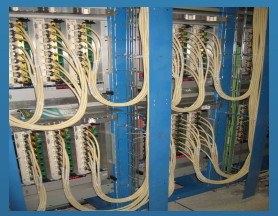
→ ***Capabilities to trigger on leptons (including taus)***

→ ***Exploit fully hadronic channels, MET/HT with decent rate***

→ ***Trigger on specific topologies such as VBF***

→ ***All this in the intense environment of the LHC***

The CMS Trigger system is organized in two consecutive levels to achieve an input data rate reduction of a factor 10^5.



Clock frequency: 40 MHz

L1 Trigger 100kHz

Coarse resolution info from Calo&Muon

High Level Trigger 1kHz

Full Event resolution

LLR since the beginning

Implication of the CMS LLR group since the beginning: The LLR has been involved in **the design, the construction, commissioning and operations of the CMS Level-1 Calorimeter Trigger**.

→ ***Design of the 108 TCC electronics boards which are used to handle the Trigger Primitive Generation based on the ECAL information.***

LLR responsibilities: The LLR is responsible for the maintenance and improvements of the ECAL TPG system during the Phase I (MoA)

ECAL trigger coordinator (L2): A. Zabi
Electronics engineers : Y. Geerebaert & T. Romanteau (designers of the TCC)
Software engineers : F. Magniette and F. Thiant (designers of the software)
Performance: I. Antropov, C. Ochando, S. Regnard.

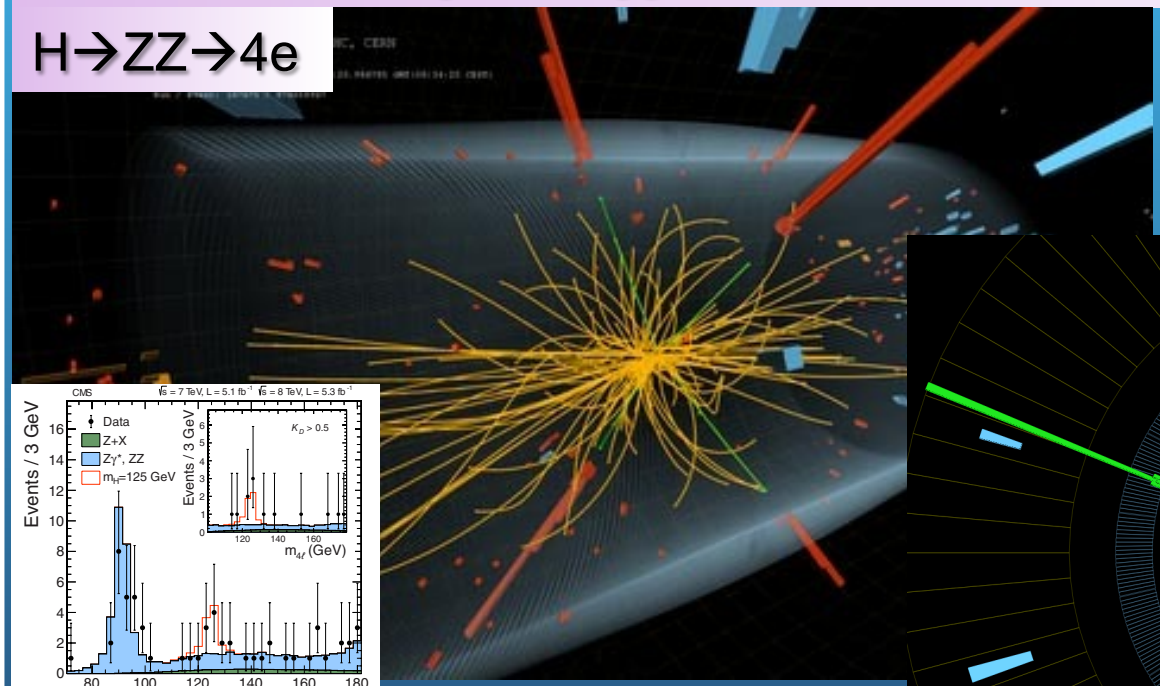
→ *Considered one of the most reliable system of CMS.*

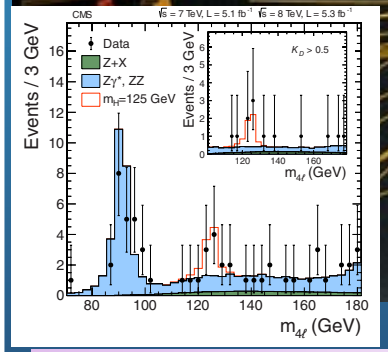
Highlights of the Run I

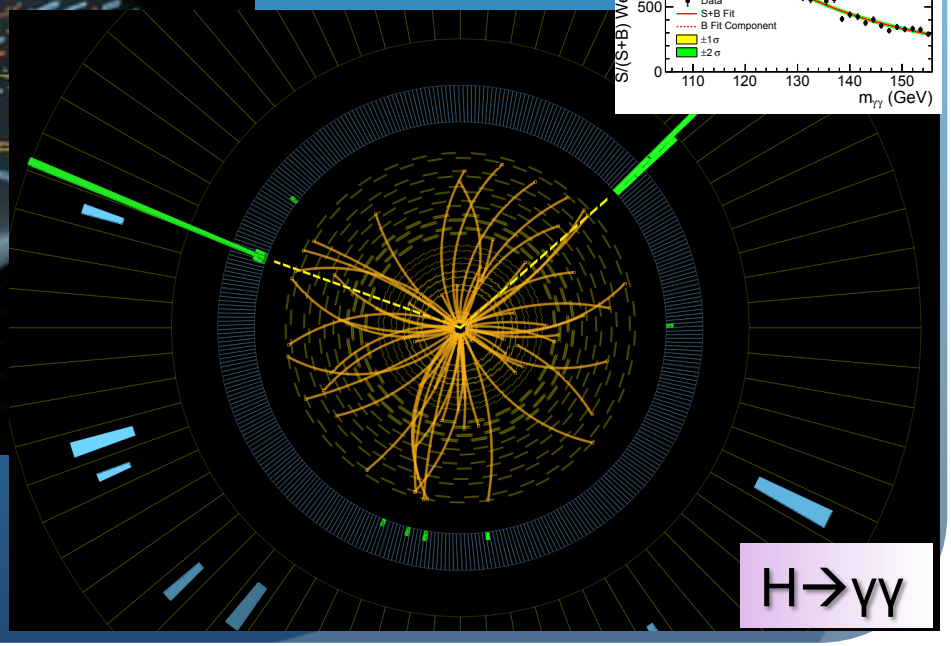
From the commissioning to the first physics and the discovery of the Higgs boson: The TCC installation was completed in 2009 with the TCC Endcap. The system has successfully triggered with the first collisions in 2010 and ever since.

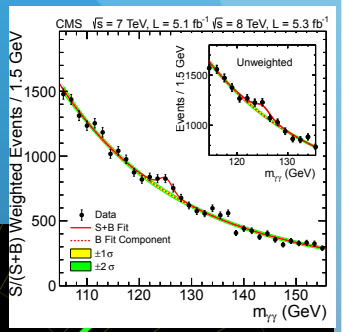
→ ***The LLR was involved in all steps that lead to the discovery of the Higgs boson including the trigger that selected these events!***

H→ZZ→4e









Both triggered by DoubleEG_13_7

H→γγ

Highlights of the Run I

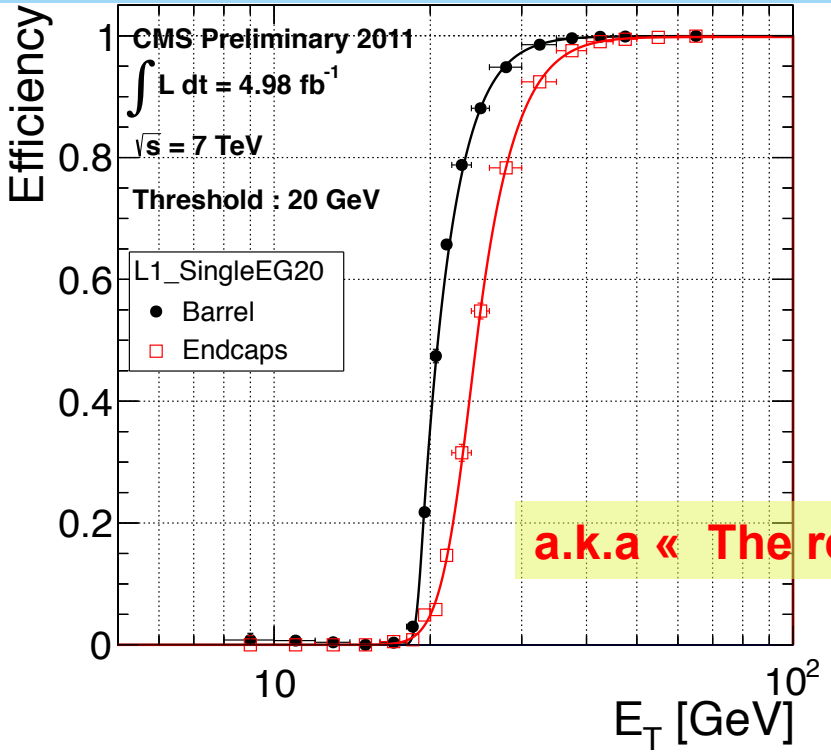
Study and optimization of the electron and photon performance: The LLR trigger team has produced ALL the EG trigger performance plots since 2008.

→ ***These results have been published and presented in many conferences***

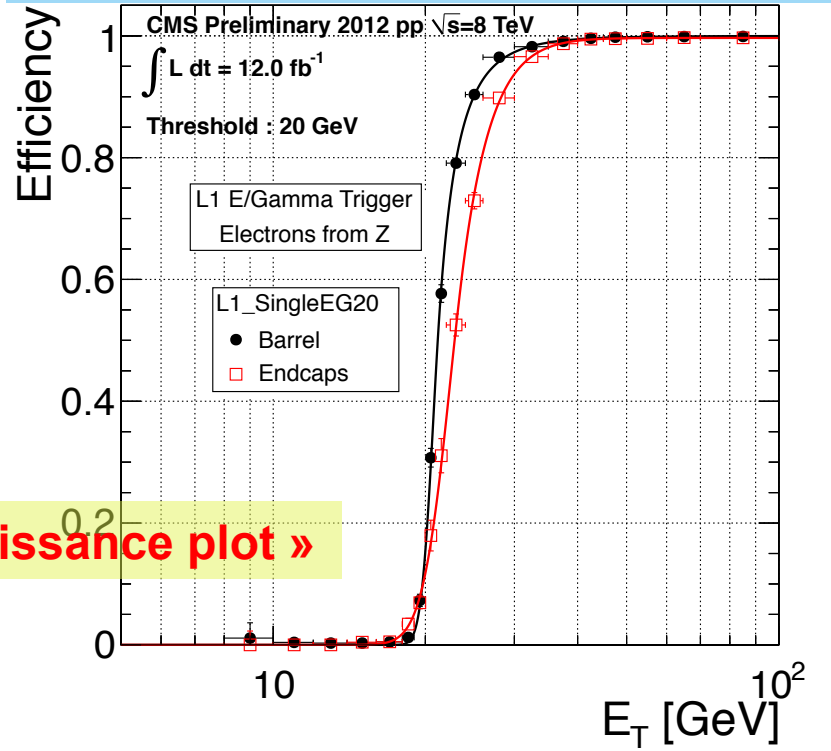
→ ***Systematic studies that allowed to optimise the fonctionning for physics:***

Lowest unprescale trigger EG20, 99.8% of active channels, spike killer etc…

LEVEL1 EG20 2011



LEVEL1 EG20 2012

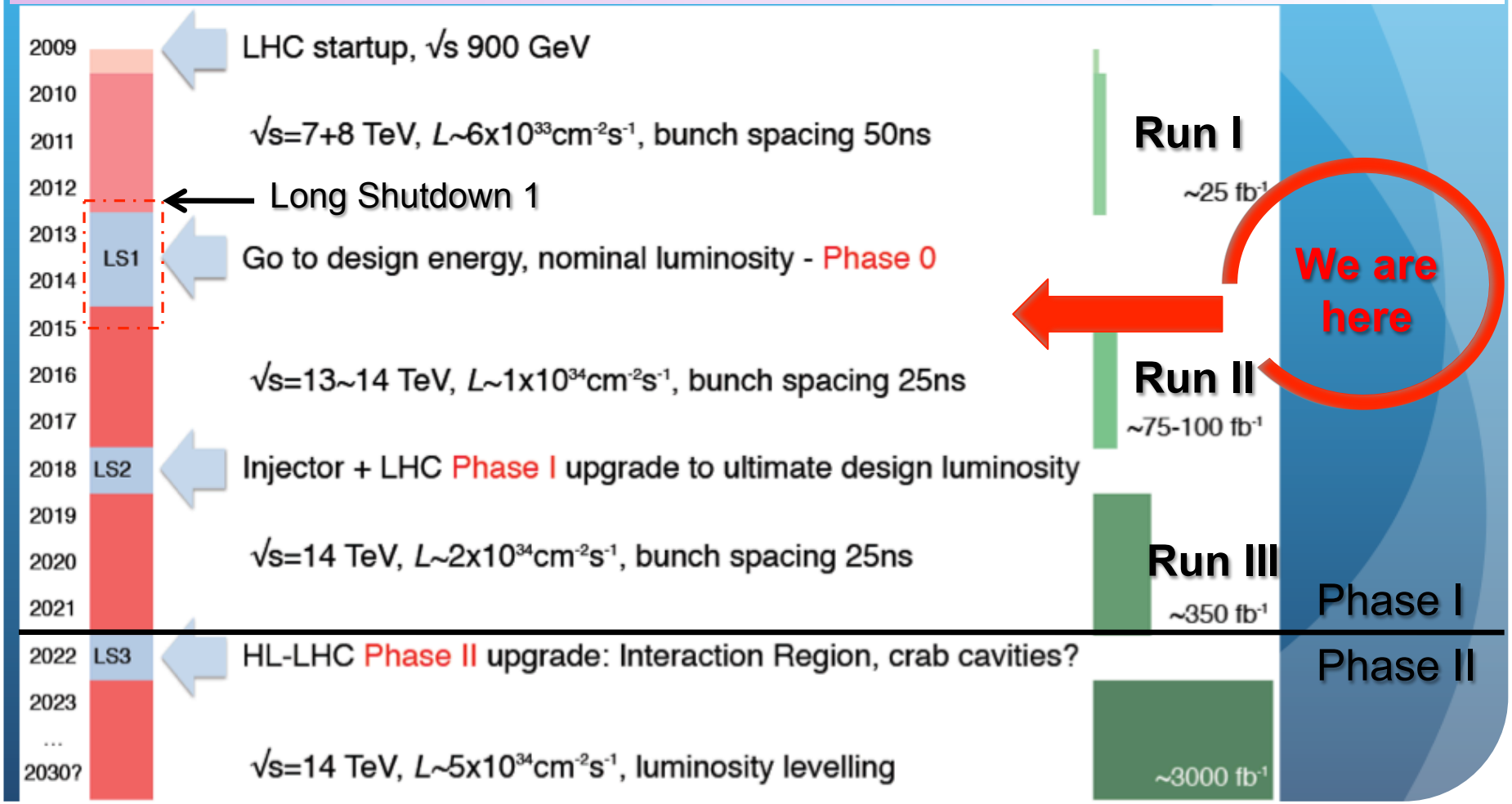


a.k.a « The renaissance plot »

Operation of the Trigger

One upgrade after the other: Starting this year, the LHC intends to deliver an instantaneous luminosity beyond the original specifications of the machine.

→ ***The LLR is involved in the upgrade of the calorimeter trigger system***



Phase I Trigger Upgrade

Triggering algorithms for high luminosity: The NEW Stage-2 calorimeter trigger has been designed to select efficiently events based on calorimeter objects in the **high luminosity and high pile-up regime foreseen for the LHC RUN II**

→ ***Maintain the thresholds for physics, improve single object performance (energy and angular resolutions) introduce new variables/cross-triggers.***

Electrons and photons:

→ Dynamic clustering to recover brem energy (improve resolution)

→ Benefiting from the enhanced granularity to use cluster shape identification and reconstruct precisely the position

Tau leptons : Built from EG clusters (merged) to optimize reconstruction area

→ Better position and energy resolution

For Taus and EG :

→ Adapted energy calibration at Layer-1 and Layer-2

→ pile-up subtraction isolation and configurable (LUT)

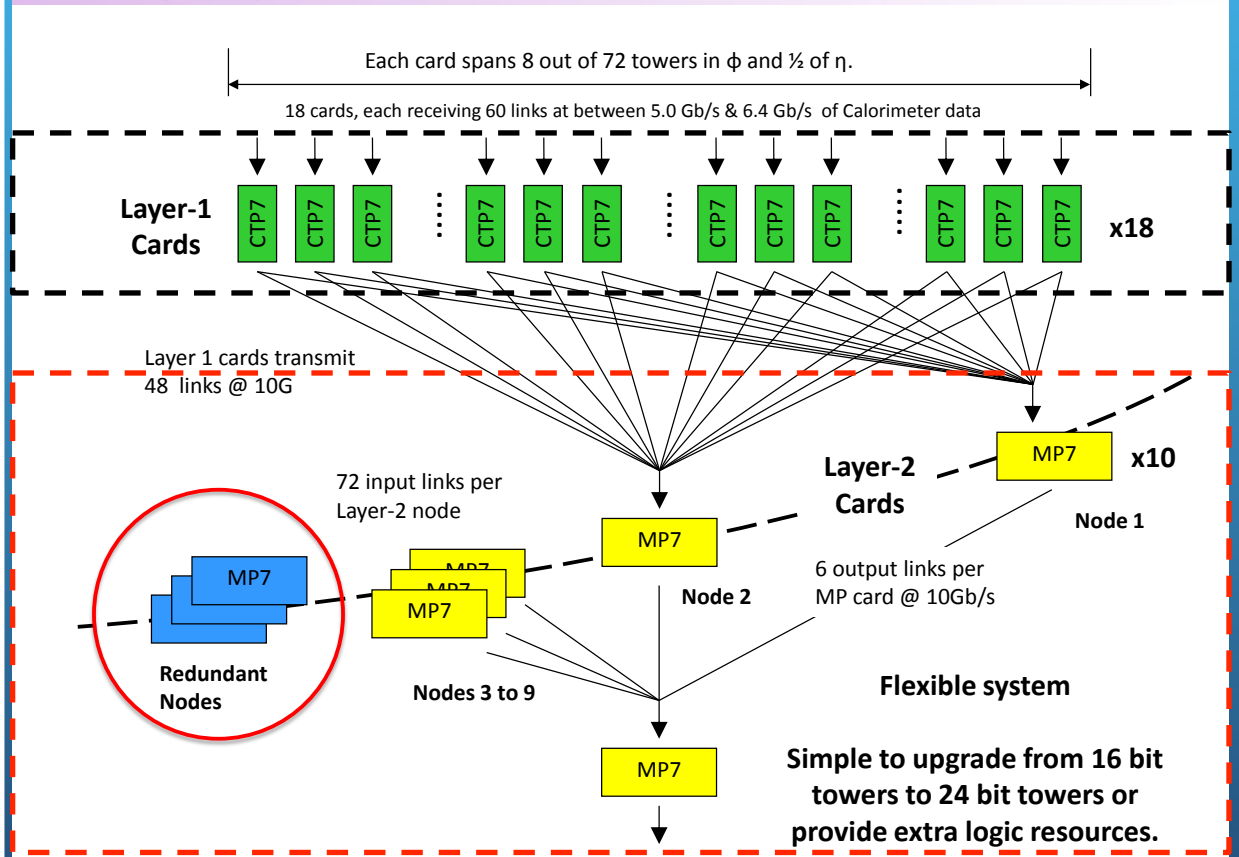
Team: F. Beaudette, L. Cadamuro, O. Davignon, T. Romanteau, J. B. Sauvan, T. Strebler and A. Zabi

→ *Collaboration with Imperial College*

Novel Trigger concept: TMT

New technology (uTCA) ←→ Innovation in terms of architecture:
→ Implementation of the **Time Multiplexed Trigger (TMT)**

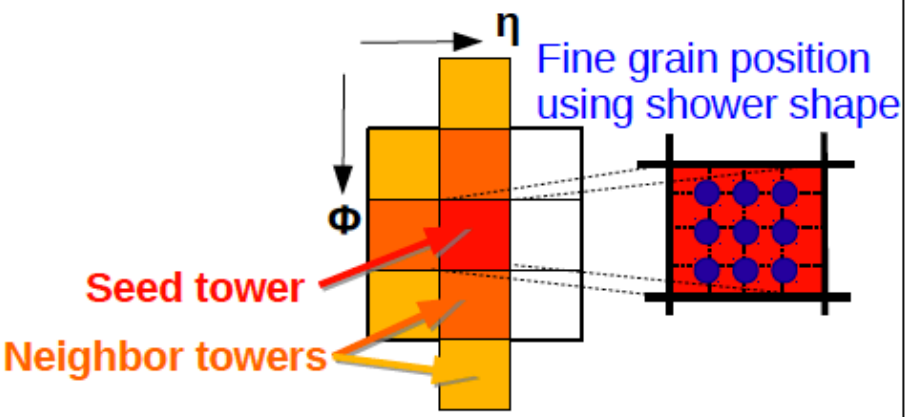
1152 input optical links from ECAL, HCAL and HF



P2IO R&D:
Project PRIVAT: installation of a platform with MP7 boards to develop and test algorithms

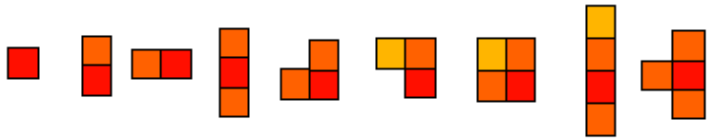
New EG and TAU algorithms

Dynamic clustering with shape constraints



- Better energy containment
  - ↳ Showering electrons, converted photons
- Small impact of pile-up

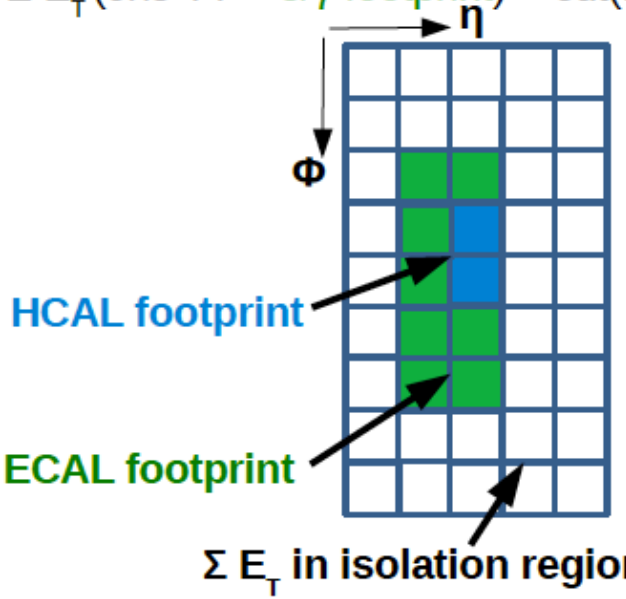
Examples of cluster shapes



Discriminate e/γ against jets
Veto clusters with specific (jet-like) patterns

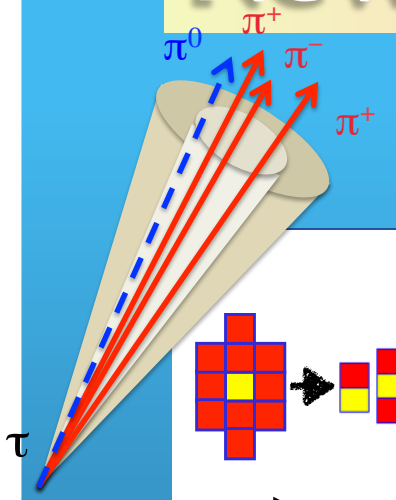
Isolation (ECAL+HCAL)

ΣE_T (9x5 TT – e/γ footprint) < cut(PU, η)



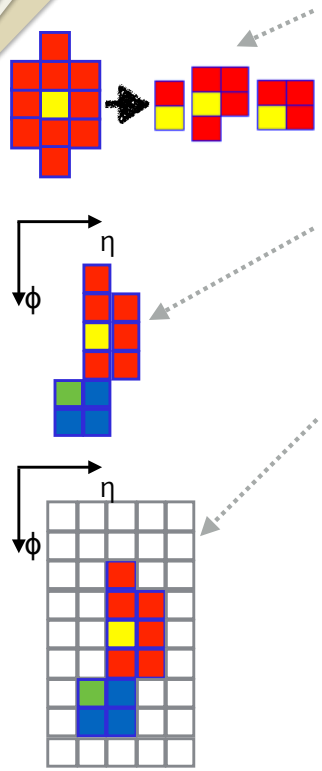
- Use an isolation E_T cut that is a function of pile-up
  - ↳ Use the number of trigger towers above a threshold as pile-up estimator
  - ↳ Tuned for constant 90% efficiency vs η and PU

New EG and TAU algorithms



Hadronic tau decay (70%)

→ Rather complex object : several clusters spread in phi



Clustering
- TT are regrouped into clusters
- Basic object to form L1 tau candidates

Merging
- Search for neighbors in a defined path (tau decay products can be spread out)
- ~**15%** merged, **85%** non merged

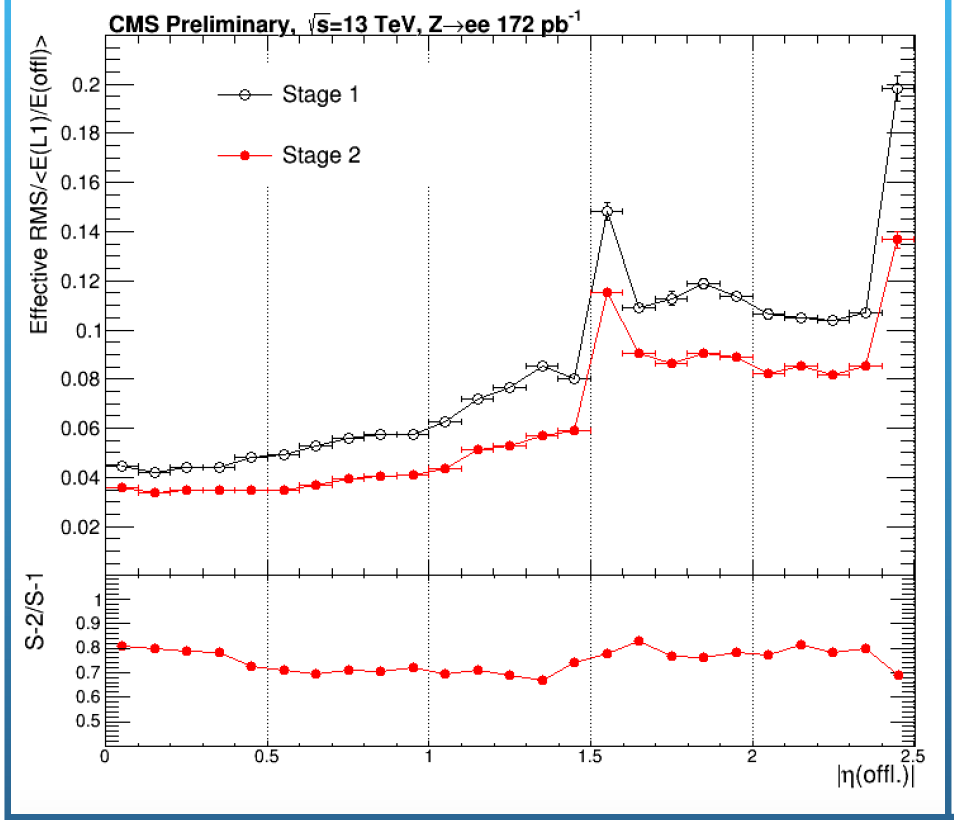
Isolation
- Compute isolation as E(5x9) - E (tau)
- **PU subtraction at hardware level**

Calibration
- Use of ECAL and HCAL energies separately to calibrate tau energy
- Function of eta position

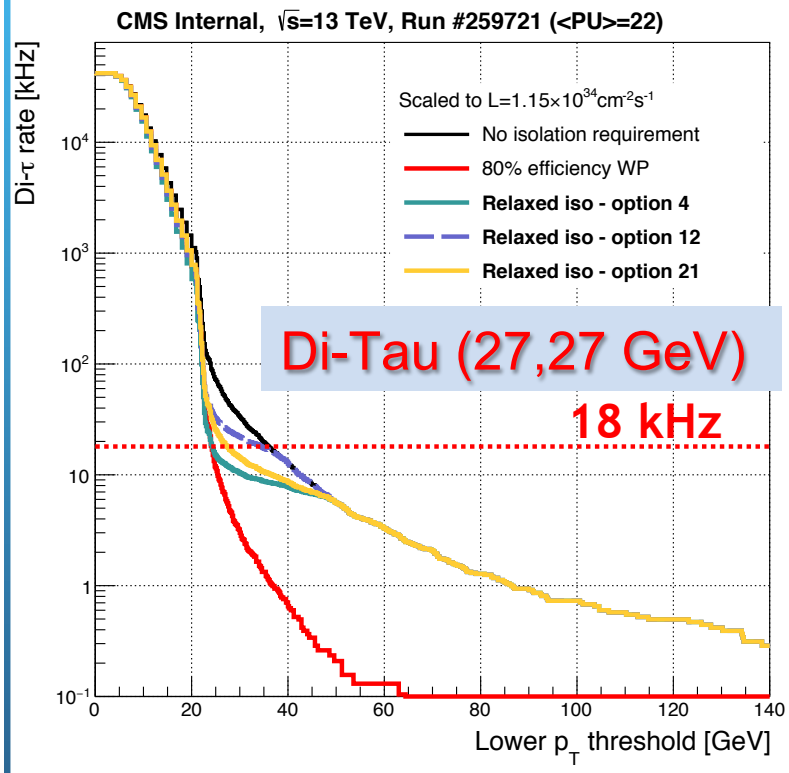
Shape veto
- Cluster with certain shapes are rejected
- Additional background rejection

New EG and TAU algorithms

EG trigger object resolution



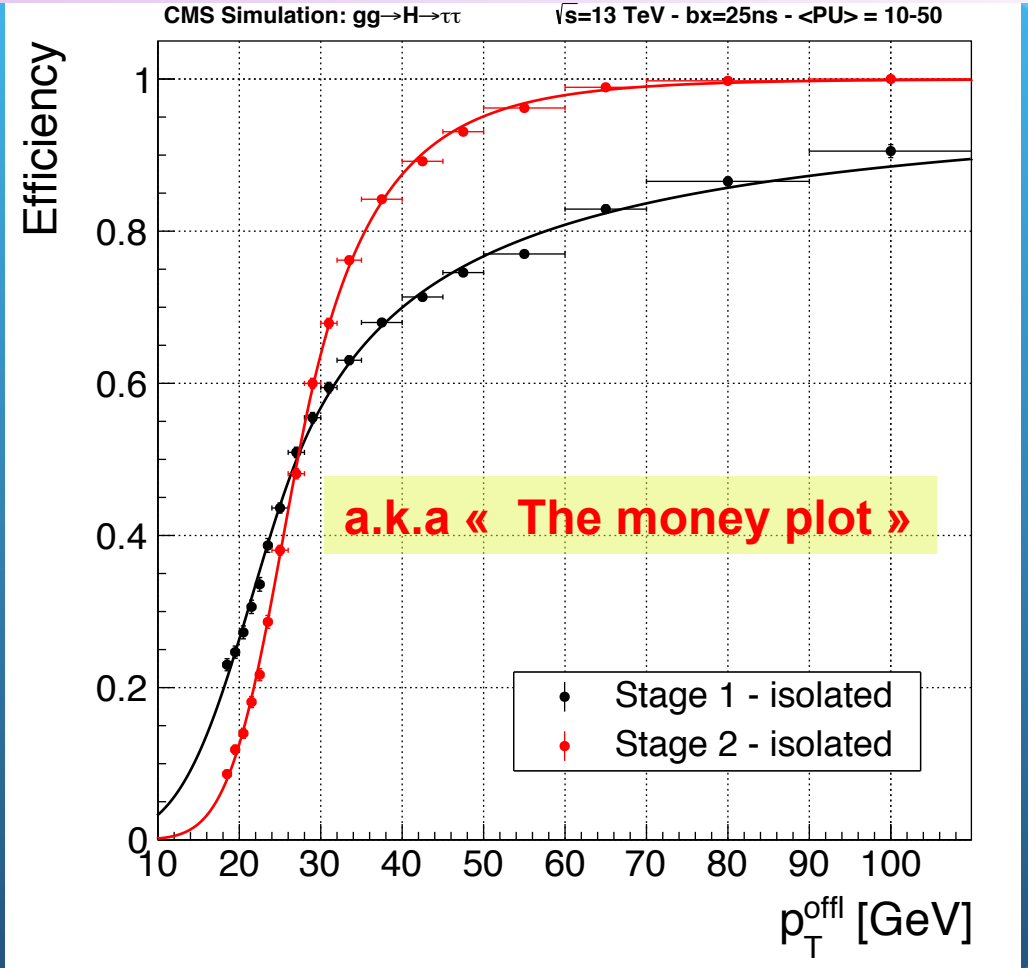
Di-Tau Trigger rate



→ First acceptance results **+8 %** on H→4l, first Mee trigger **+5%** on Zee
→ **+15%** of acceptance for H→tau tau (w/o VBF!)

New EG and TAU algorithms

Large improvement on the EG and TAU trigger performance with respect to Stage-1 (2015 improved trigger)



CURRENT ACTIVITIES

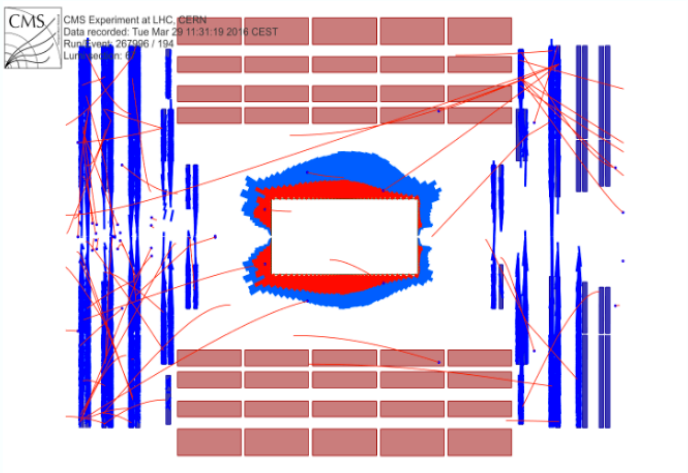
Intense Stage-2 testing in P5 since 2015 parallel running:

→ Validation during long cosmics Runs (during MWGR)

→ Triggering on splashes and first beams

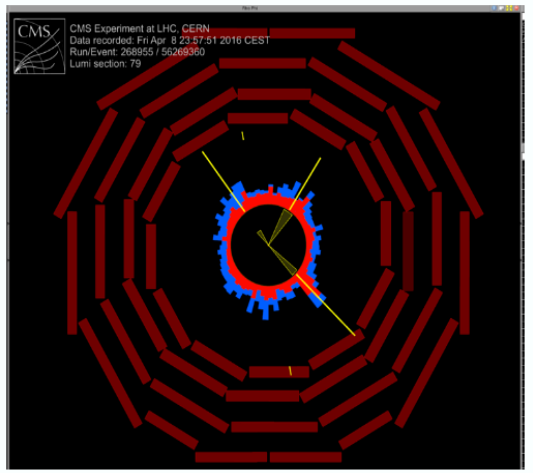
Tuesday 29th March

successful triggering of beam splash



Friday 8th April

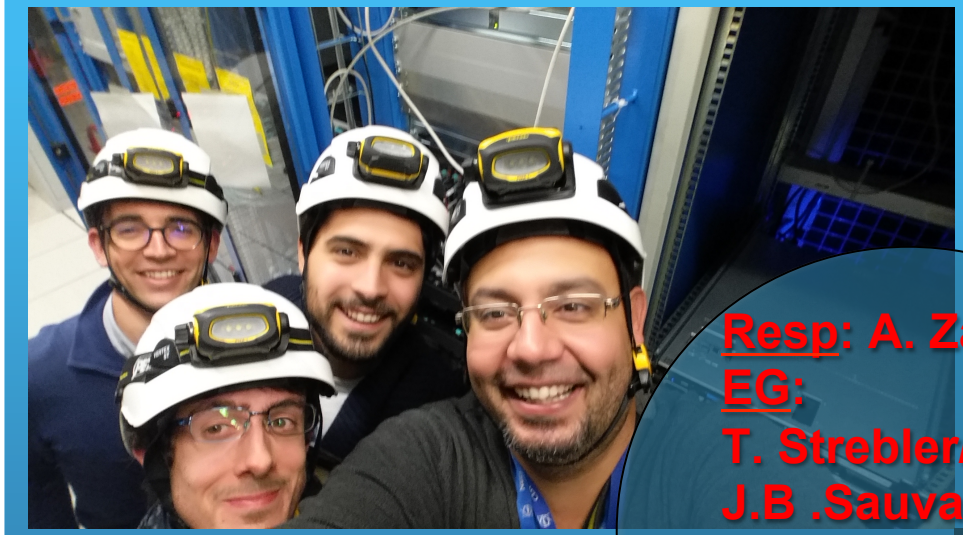
first non-stable beam collisions



Successfully triggering on splashes, first quiet beams and now collisions!

Final timing verification → Aligned (triggering on correct BX)

CURRENT ACTIVITIES



Resp: A. Zabi
EG:
T. Strebler/
J.B .Sauvan
TAU:
F. Beaudette
L. Cadamuro/
O.Davignon

TAU POG: Tools/ trigger contact/VBF trigger develop

EGAMMA POG/ECAL DPG: performance + software tools

L1 DPG: Trigger algorithm and optimisation

TSG: optimisation for menu developement and strategy

OPERATIONS
Prompt feedback

The Trigger and the group

The CMS LLR trigger activities: Given the involvement and expertise of the group, the trigger is a **natural project to join and contribute technically to CMS**. Over the years our students, postdocs, physicists and engineers have contributed to all aspects of the trigger.

→ **Operations**: Participations to shifts and development of monitoring tools
→ **Performance studies**: rate & resolutions, sources of inefficiencies
→ **Optimization**: Spike killer, laser corrections etc..
→ **Algorithm development**
→ ***Active role in data taking*** *(presence in the control room)*
→ *Etc..*

More than 12 internship students on the trigger since 2010 (2/year)
Major contributions → Visibility of students and postdocs (N. Daci CMS achievement award for the spike killer), presentation in collaboration meetings etc.
Talks and Posters on trigger studies presented at international conferences every year!

From Phase I to Phase II

Benefiting from the experience of Phase I to prepare Phase II: The LLR team is involved in the developments of the trigger system for phase II.

- → ***P2IO R&D 2013: finance platform for trigger development used to design the trigger algorithms to be used in future Level-1 trigger.***
- → ***Strong expertise in Trigger Primitive Generation algorithms and schemes: important role in the definition of the TPG architecture for HGCAL***
- → ***Strong expertise in the design of electronics systems and high-speed optical links (Gb transceivers etc.)***
- → ***More in C. Ochando's talk***