Towards τ Reconstruction In High Luminosity LHC(HL-LHC) With a High Granularity Endcap Calorimeter

A. Izadi Rad (Sharif University of Technology, Iran), P. Tereziu (Faculty of Natural Sciences, University of Tirana)
Supervisors: M. Mannelli, P. Silva (CERN-CMG)

Abstract

The goal of our project is to contribute to the study of the performance of the High Granularity Calorimeter (HGCal) designed to operate in Phase II of the CMS detector at the High Luminosity LHC (HL-LHC).

Higgs physics prospects at the HL-LHC

- In July 2012, ATLAS and CMS discovered a SM Higgs-like particle using ~25 fb-1 of 7-8 TeV pp data
- Nature of the particle not yet fully established :

spin, CP, couplings will benefit from high luminosity

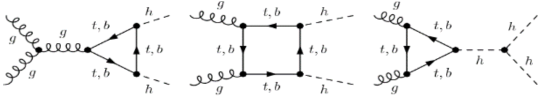


Fig.1

- **Self coupling measurements will become feasible with higher energy and luminosity**

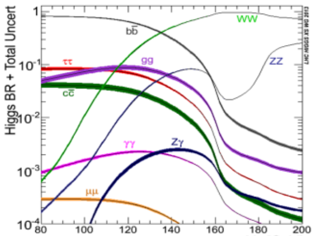


Fig.2

τ *properties*

Mass m = 1776.82 ± 0.16 MeV

cτ = 87.11 μm

particle $^-$ ≥ 0 neutrals ≥ $0K^0\nu_\tau$ ("1-prong")	(85.35 ± 0.07) %
$\mu^-\bar{\nu}_\mu\nu_\tau$ / $e^-\bar{\nu}_e\nu_\tau$	(35.24 ± 0.06) %
$h^-h^-h^+$ ≥ 0 neutrals ≥ $0K_L^0\nu_\tau$	(15.20 ±0.08) %

Interesting channels of Higgs

Channel	BR(%)	Cross section x BR (fb)	Events expected @ 14 TeV (L=3000 fb^{-1})
bb+bb	33.41	11.33	34 k
bb+WW	24.97	8.36	26 k
bb+ττ	7.36	2.50	7.5 k
WW+WW	4.67	1.58	4.7 k
ZZ+bb (ZZ+bb →4l+bb)	3.09	1.03	3.1 k (→13.9)
ZZ+WW	1.15	0.39	1.2 k
gg+bb	0.27	0.09	270
bb+μμ	0.013	0.004	12.8

Table 1

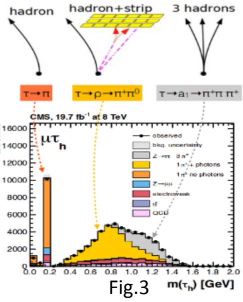


Fig.3

- The High Luminosity-LHC is expected to be crucial providing ~3fb^{-1} at 14 TeV

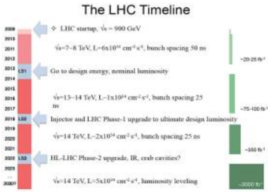


Fig.4

Higgs self coupling measurements feasible only at HL-LHC

Major detectors upgrades to cope with higher radiation levels, higher occupancy and required data rates:

-Replacement of critical components,

-Upgrades to trigger and electronics

High Granularity Calorimeter (HGCal)

-High granularity calorimeter have been proposed as future ILC/CLIC detectors

-Provide high resolving power for single particles in dense jet environment

-At the HL-LHC it offers the prospect of resolving single particles and jets in a dense pileup environment

Table 2

Sub-Detector	Active Medium	Passive Medium	# Layers	# Channels	Thickness
Electro-magnetic	Si	Pb+W	30	6M	25 X_0 / 1λ
Front Hadronic	Si	Brass	12	2.7 M	3.5λ
Back Hadronic	Plastic Scintillator	Brass	10	~1M	5.5λ

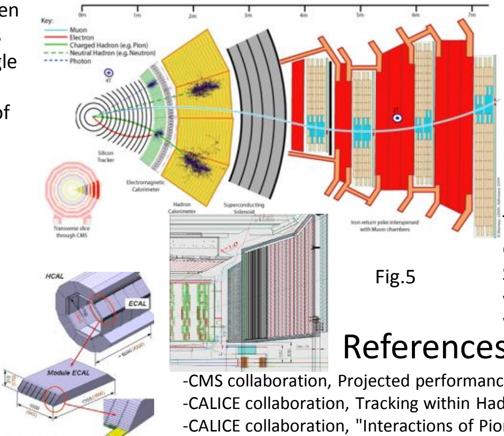
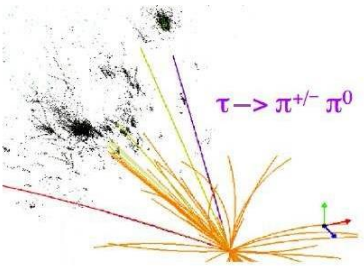


Fig.5

Towards τ reconstruction

τ leptons have a mass of ≈1.8 GeV and a lifetime cτ=87.1μm. They can decay through electroweak interactions into a μ or an e and two neutrinos, although this amounts to only 34% of their decays. The remainings proceed to final states which contain mesons and a τ neutrino. The most abundant ones are π⁻



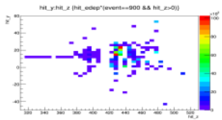


Fig.6

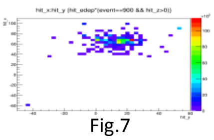


Fig.7

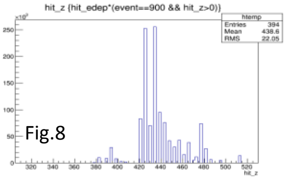


Fig.8

-CMS work in progress

Spatial distribution of the energy deposits in the layers of HGCAL: Fig.6 y-z view, Fig.7 x-y view. The total energy deposited per layer is shown in Fig.8

π$^\pm$ reconstruction

π$^\pm$ MASS	139.57018 ±0.00035 MeV
π$^\pm$ MEAN LIFE	(2.6033 ±0.0005) ×10−8 s

π$^\pm$ are charged hadrons which interact mostly in the hadronic calorimeter.
In the electromagnetic calorimeter they are expected to leave low energy ionization deposits.
Showers are expected to be wider with respect to π^0.

π^0 reconstruction

$$m_{\pi^0} = 134.9766 \pm 0.0006\mathrm{MeV}$$
$$m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005\mathrm{MeV}$$
$$c\tau = 25.5nm$$

2γ	$(98.823 \pm 0.034)\%$
$e^+e^-\gamma$	$(1.174 \pm 0.035)\%$
$e^+e^-e^+e^-$	$(3.34 \pm 0.16) \times 10^{-5}$

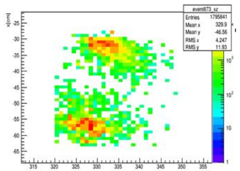


Fig.9
Resolved

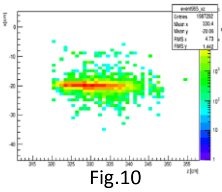


Fig.10
Partially resolved

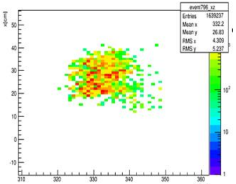


Fig.11
High energy, collimated

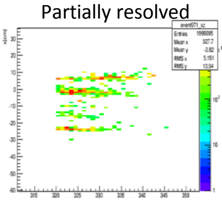


Fig.12
With conversions

Neutral pions decay mostly to two photons. As the decay products interact electromagnetically it is detected in the electromagnetic calorimeter.
Due to interaction with the tracker material we may observe several electromagnetic showers developing in parallel.

Exploring the shower structure

By looking at the structure of energy deposit in the Calorimeter we can study :

- How collimated the shower is
- How many particles it contains

A Hough transform can be used for this purpose.

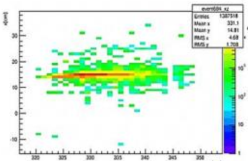


Fig.13

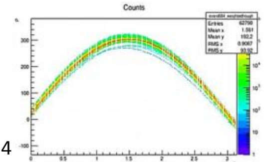


Fig.14

The total accumulated in the maximum of the Hough transform can help us distinguish between single and multiparticle showers.
Single photons are expected to produce collimated, high energy showers while neutral pions tend to produce multiple-core showers of lower energy.
We are exploring these properties for particle identification.

References

-CMS collaboration, Projected performance of an upgraded CMS detector at the LHC and HL-LHC, CMS-NOTE-13-002
-CALICE collaboration, Tracking within Hadronic Showers in the SDHCAL prototype using Hough Transform Technique, CAN-047
-CALICE collaboration, "Interactions of Pions in the CALICE Silicon-Tungsten Calorimeter Prototype", CAN-050