WP1: “New particles search”

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Mandate of WP1

Objective of WP "***New particles search***" is to perform reconstruction, analysis and simulation of collision events produced in CMS. The research work will concentrate on two main subjects, already studied since several years by some participants.

- In the Standard Model (SM), the origin of the mass of particles is believed to be the "Higgs mechanism" which predicts the existence of Higgs particles. The mass of these particles is in a range attainable by the present energy and luminosity of the Large Hadron Collider (LHC). After two years of successful operation in 2010/2011, the LHC has already restricted significantly the mass range of existence of a possible Higgs boson. Next two years will be crucial to assess a possible discovery or a possible exclusion confirmation in the observable LHC mass range. New analysis algorithms and massive simulations are needed to this aim.

- Nevertheless, the SM does not unify electroweak and strong interaction, it does not include gravitation, and it is not satisfactory when extrapolated to energies higher than the electroweak symmetry breaking scale. New ideas are thus needed and their physical manifestations are expected at the LHC. The best-motivated extension is Supersymmetry, for which a large variety of models exist. Investigating the phenomenology of some of them, which predict either new heavy particles or observable deviation from the SM and comparing to the available data, is one objective of the network. New particles, such as heavy vector bosons, predicted by the extension of the SM to higher symmetry groups, may also appear experimentally. These particles could also exist if there are extra dimensions of space-time. For example, the largely quoted Randall-Sundrum theory would solve the problem of hierarchy between the strength of the gravitation compared to the other interactions.

WP1 tasks

Task 1.1: *Search for Higgs particles*

In most of the relevant Higgs particle mass region, the decay channel to ZZ* and finally to four leptons (electrons or muons) provides an opportunity for early discovery or the setting of exclusion limits. The search in this channel consists of identification and reconstruction of four electrons and/or two electrons and two muons and suppression of the backgrounds, among which the continuum ZZ* production is the most important. Electrons and muons transverse momenta are between 5 and 100 GeV/c. The reconstruction of electrons is more demanding at low energy due to the electron bremsstrahlung effect in the tracker material; in this case emphasis on the development and optimization of specific reconstruction algorithms is required.

Task 1.2: *Search for heavy new particles beyond the SM*

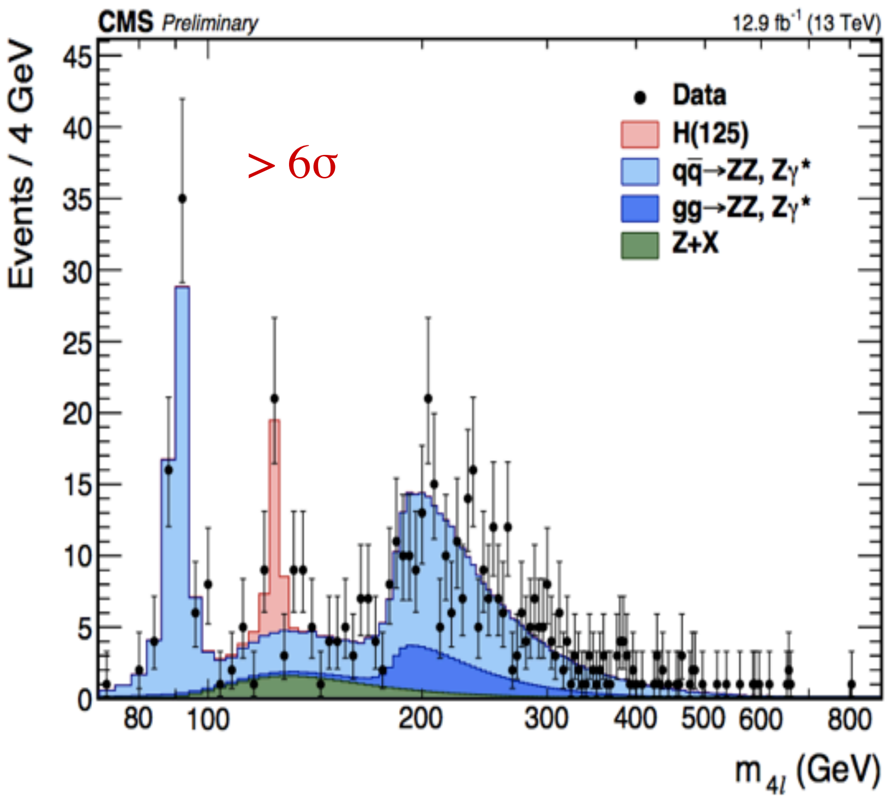
This search consists of finding peaks in the electron and positron pair spectrum over a continuous background. In this channel, the energies of the electrons range from several tens GeV to more than 2 TeV. Specific methods of calibration, selection and reconstruction are needed. This is already in progress, together with the implementation of a method to deal with saturation of the calorimeter. The background is predicted to be low but, due to the small number of expected events, a powerful statistical analysis is required.

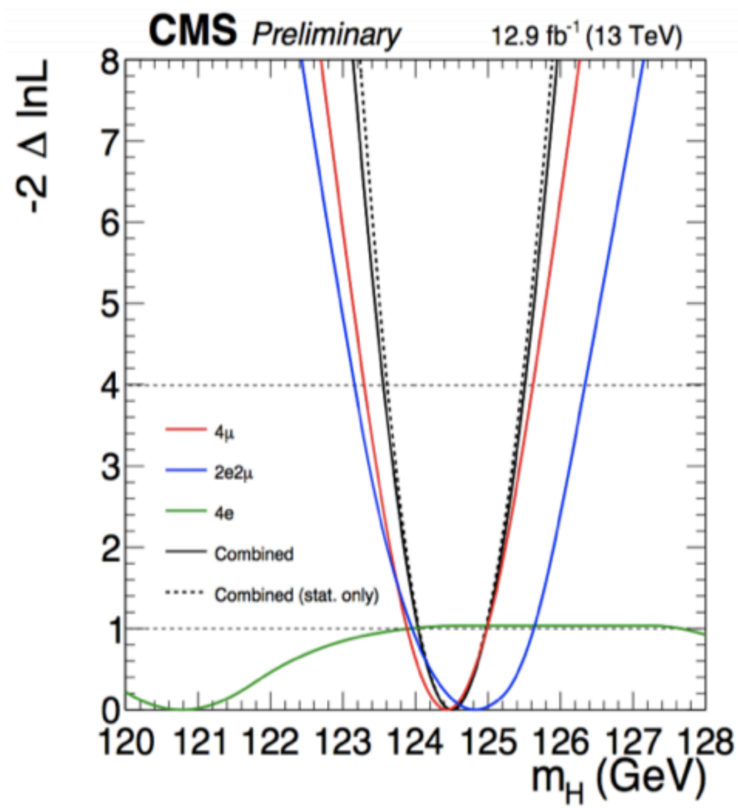
Task 1.3: *Set up of a CMS center for data analysis at AIN SHAM*

The set up of a local Egyptian center for CMS data analysis is one of the main objectives. In parallel with the training of young scientists, an effort to develop new infrastructures in Egypt is necessary to create an autonomous research context and boost the activity by offering new opportunities to students. AINSAM has already some experience and some basic software infrastructure. Under the advice and help of researchers from POLIBA and ECOLE, one expects the AINSHAM group to consolidate the expertise and to improve the software /hardware capabilities for future involvement in advanced analysis of the CMS data.

Task 1.1: Higgs @ 13 TeV

- Continuous work on the SM H→ZZ→4l analysis
- Re-discovery of the Higgs@13 TeV





$$m_{\rm H} = 124.50^{+0.48}_{-0.46}\ {\rm GeV} = 124.50^{+0.47}_{-0.45}({\rm stat.})^{+0.13}_{-0.11}({\rm sys.})\ {\rm GeV}$$

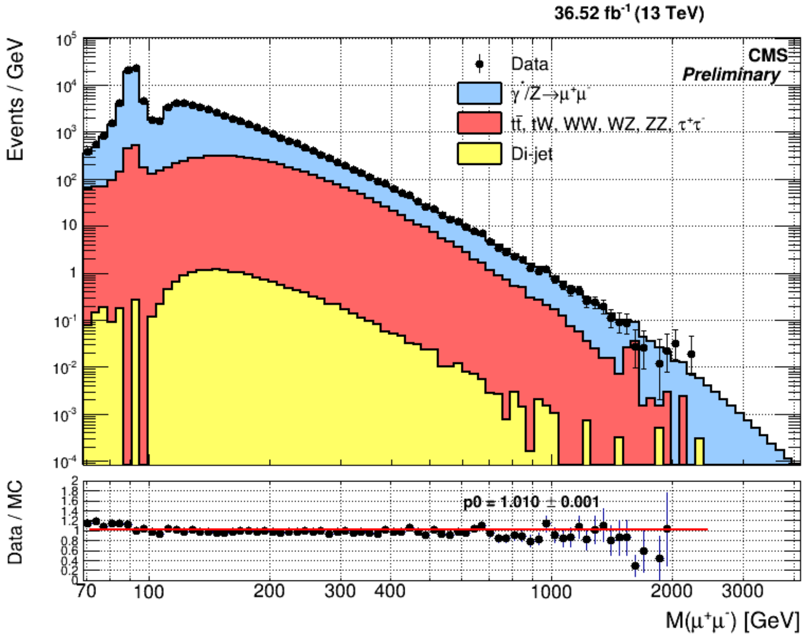
Task 1.2: Search for Z'→ee,mumu:

Grand Unification Theories (GUT's) suppose that strong and electroweak interactions can be described by a simple gauge group.

That is realized by introducing a larger gauge group then at least one extra neutral gauge boson Z' should exist.

In the sequential Standard Model (ICHEP16):
Z'_{SMM} < 3.75 TeV excluded @95C.L.

In the superstring-inspired (ICHEP16):
Z'_{ψ} < 3.2 TeV excluded @95C.L.



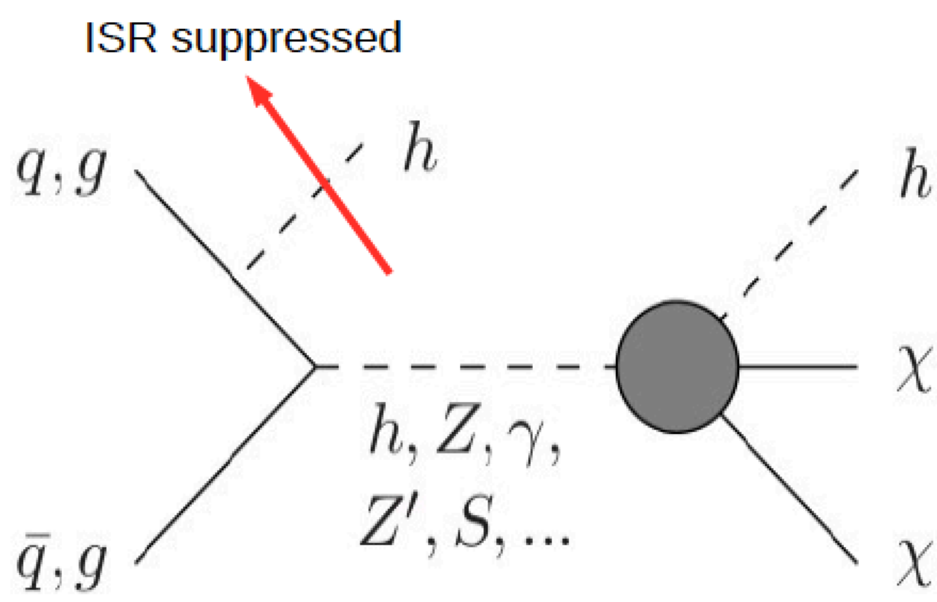
Currently working on:

- Z'→ ee and Z'->mumu analysis strategy
- TeV reconstruction and ID
- Background estimation - multijet
- Systematics
- **RELEVANT EFFORT in 2016 → Moriond 2017**

(S. Elgammal)

Task 1.2: Mono-Higgs

- Higgs discovery provides new portal into DM coupling to SM
- DM searches at the LHC include analyses with mono-X + MET signatures for X=W, Z, jet, and γ
  - ATLAS 8 TeV mono-H → γγ
- In general, X can be emitted as ISR or from the new vertex coupling DM to SM
- Higgs ISR is highly suppressed, so mono-H can directly probe the effective DM-SM coupling



Next year (Jan. 2016) Zewail and BUE will join the mono-Higgs searches in CMS

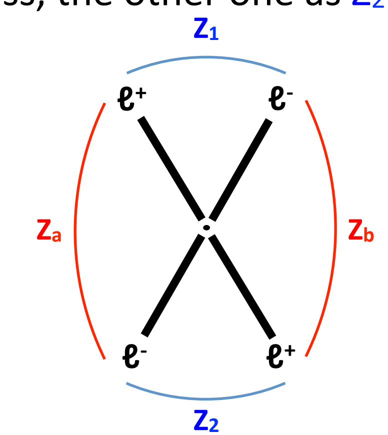
Reference papers: *arXiv:1312.2592v2 [hep-ph], arXiv:1404.3716v2* [hep-ph]

Task 1.2: Mono-Higgs

- Starting from **2015 Run 2 Standard Model H→ZZ→4l analysis** using MC Fall15 samples and data collected during 2015 at √s =13 TeV corresponding to an integrated luminosity L=2.8 fb^{-1}
- Looking for a final state H→ZZ→4l (l=e,μ) + MET
- **Lepton selection** using *tight* cuts as:
  - MUONS: p T > 5 GeV, |η| < 2.4, |dxy| < 0.5, |dz| < 1, global or tracker muons, discarding standalone; ghost removal, PF muons or trackerHighPtID with p_T > 200 GeV;
  - ELECTRONS: p T > 7 GeV, |η| < 2.5, |dxy| < 0.5, |dz| < 1, pass HZZ working point of new non-triggering MVA ID
- **ZZ candidate selection**:
  - Z candidates = OSSF pairs of fully selected leptons, 12 < $m_{ll(\gamma)}$ < 120 GeV
  - ZZ candidates: defined Z_1 as Z candidate with $m_{ll(\gamma)}$ closest to PDG Z^0 mass, the other one as Z_2.

Imposing:

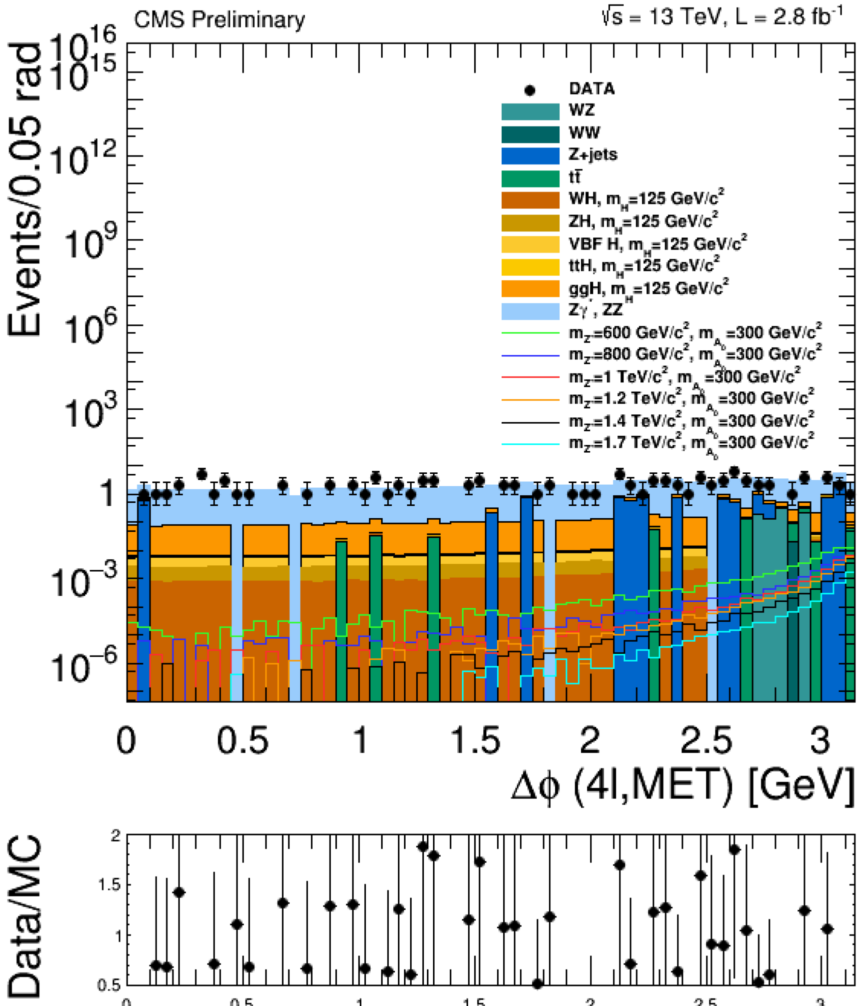
- m_{Z1} > 40 GeV, $p_T(l_1)$ > 20 GeV, $p_T(l_2)$ > 10 GeV
- ghost removal: ΔR > 0.02 between any two leptons
- QCD suppression: m_{ll} > 4 GeV for OS pairs, irrespective of flavor
- Discard 4μ/4e candidates where alternate pairing Z_aZ_b satisfies $|m_{Za}-m_Z| < |m_{Z1}-m_Z|$ and m_{Zb} < 12 GeV (→ reject « Z + low-mass dilepton »)
- m_{4l} > 70 GeV



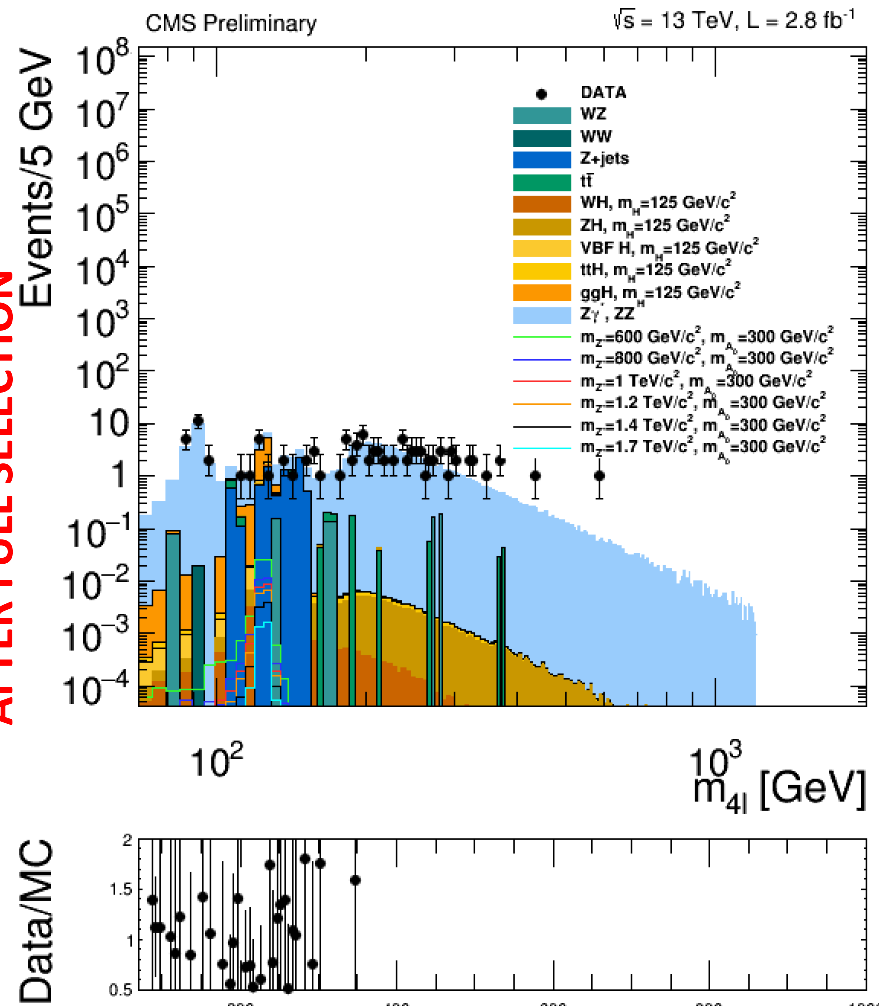
Task 1.2: Mono-Higgs – data to MC

Trigger: strategy based on ad hoc multi-lepton HLT paths:

- Mainly isolated dilepton paths: (Ele17/Mu17)_(Ele12/Mu8),
  + non-isolated trilepton paths to completely cover the phase space,
  + single-electron path (+1.5% eff. in H→4e)
- Overall >99% efficiency wrt. analysis selection



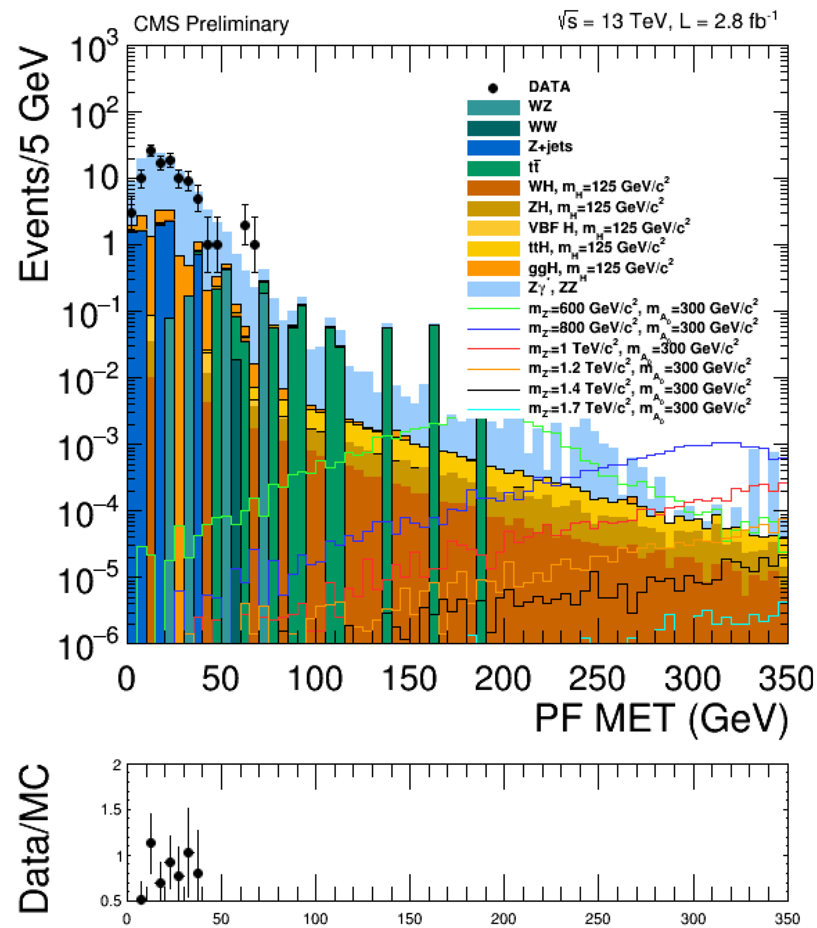
AFTER FULL SELECTION



Task 1.2: Mono-Higgs - MET

Systematics from SM HZZ4l analysis. Main uncertainties on Z+X from:

- statistics in control sample (~1-10%),
- different composition of background processes (DY, $t\bar{t}$, WZ, Zγ) in the region where we measure and where we apply fake rates (~32-35%),
- m_{4l} shapes (~5-15%)
- MET (20%)



PF MET AFTER FULL SELECTION

Task 1.2: Mono-Higgs - MET

- Search for excited leptons:
  - W. Elmetenawee, A. Abdelalalim
- Search for monopoles:
  - M. Elsawi
- Search for Heavy neutrino and Z’ (B-L) phenomenology

Summary/conclusions

People involved in 2016:

- students: A. Hammad, A.Kasem, A. Qamesh, W. Esmail, R. Aly, W.Elmetenawee, A. Fawsi, M. Elsawi
- senior: S. Elgammal, A.Abdelalim

Important achievements reached for WP1 activities:

1) Z’ analysis preparing for Moriond 2017:

2) MonoHiggs preparing Moriond 2017

Transfer of knowledge effectively realized. We need to continue to invest on young and senior people, training them and work them within the CMS experiment

Task 1.2: Heavy neutrino and Z' (B-L) phenomenology

Ahmed Ali Abdelalim, Ahmed Hammad, Shabaan Khalil http://arxiv.org/abs/1405.7550

In this paper we studied the possible signatures at LHC of the heavy neutrinos and neutral gauge bosons Z' in a TeV scale B-L extension of the SM. We showed that because of the new decay channels of Z' into heavy and/or inert neutrinos current bounds on Z' mass can be relaxed. We analyzed several signatures in detail:

- $4\,l + 2\,\upsilon_l$
- $4\,j + 2\,l$
- $3\,l + 2\,j + \upsilon_l$

We showed that the most promising channel is $4\,l + 2\,\upsilon_l$.

A comparison with the proper SM background. Moreover a comparison with the SSM were also done.

Hammad defended his thesis this year