Centre de Physique des Particules de Marseille CPPM

Progress and prospects of ttH/WH,H→WW

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On behavior of CPPM/IHEP

ttH/WH, H→WW CSC(*CERN-OPEN-2008-020*) contributors
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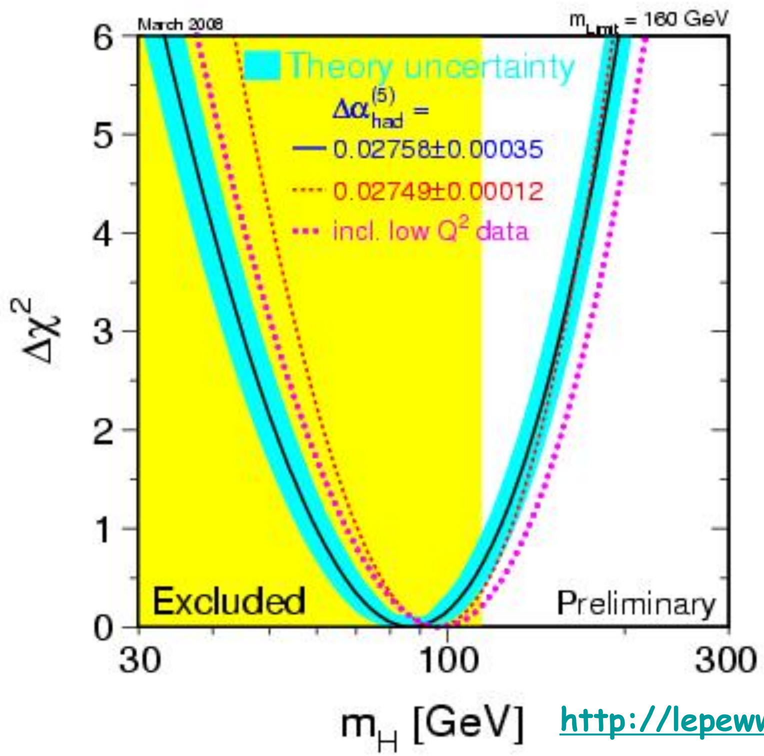
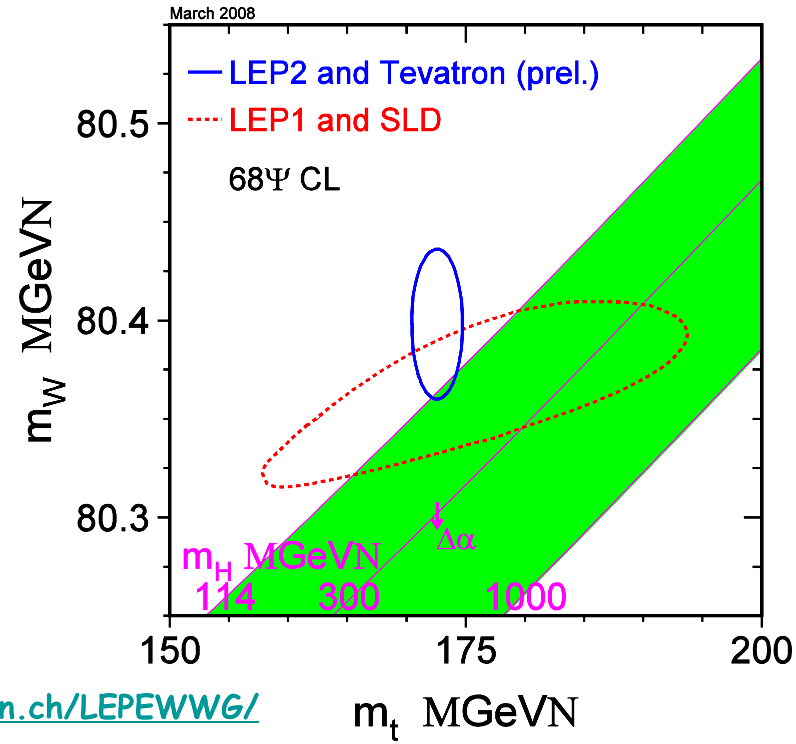
And more generally all members of CPPM and IHEP

Outline

- Motivation
- ttH,H→WW 2/3 lepton final states analysis
- WH,H→WW 3 lepton final state analysis
- ttH/WH,H→WW Strategies for real data
- Summary and prospects

SM Higgs searching in experiments

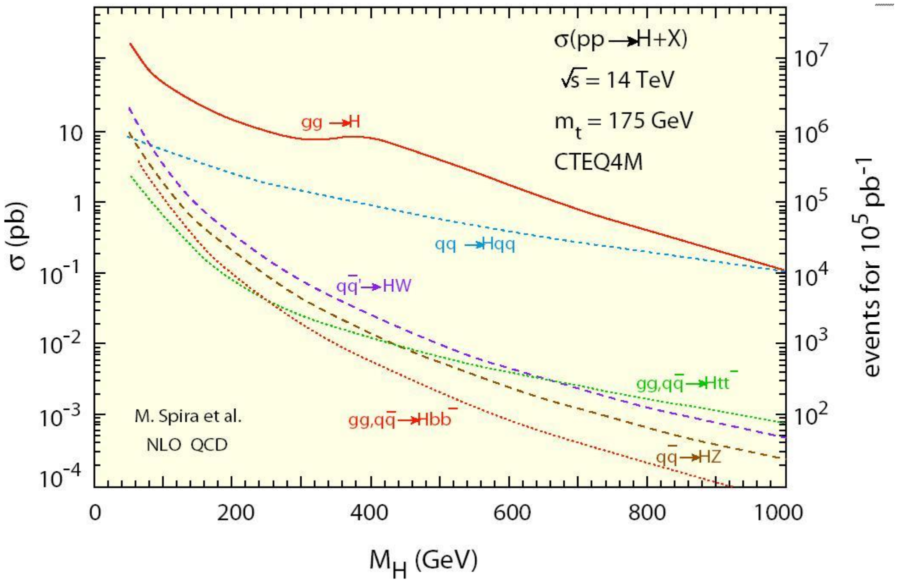


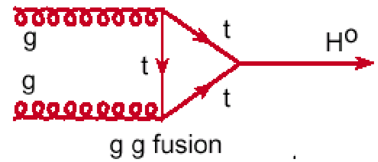


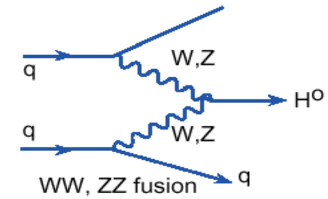
http://lepewwg.web.cern.ch/LEPEWWG/

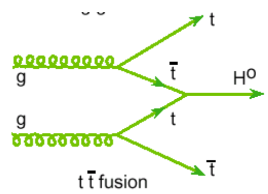
- **Higgs particles is the only particle that predicted in SM but not found yet experimentally**
- **LEP direct search exclude light Higgs below 114 GeV**
- **With recent Tevatron results, SM electroweak fit prefers Higgs less than 190 GeV (including LEP) and [160,170] GeV without.**
- **Higgs Coupling to top quarks and W boson are important properties of Higgs**

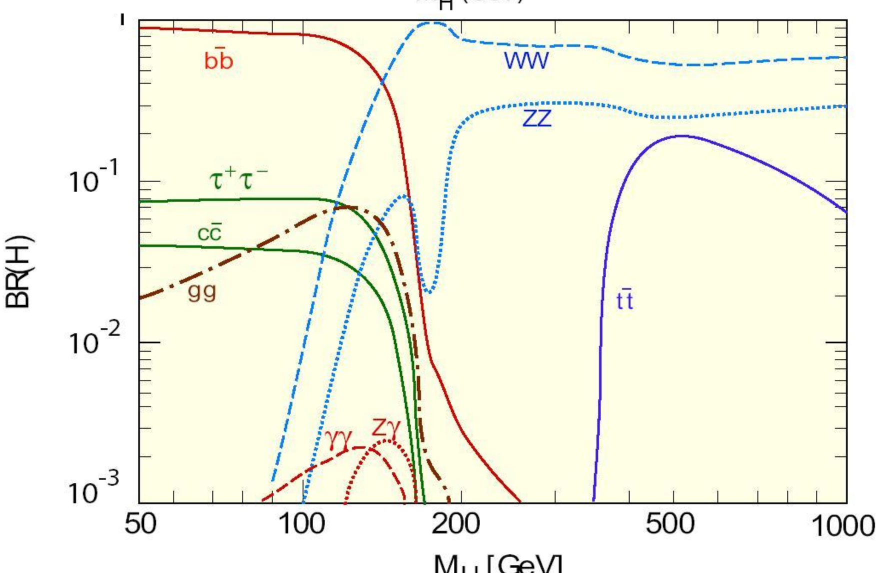
The SM Higgs at the LHC









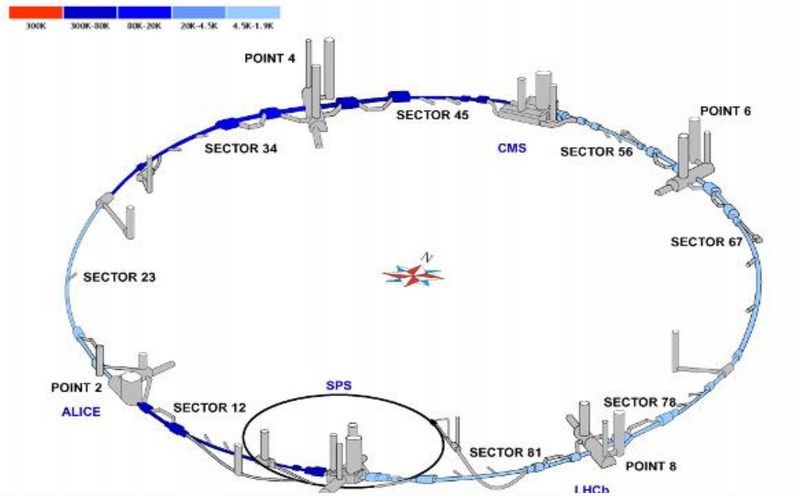


- Associate production:
  - Coupling measurement for Higgs mass [120, 200] GeV => SM Higgs or not
  - Important especially for Yukawa coupling gt.
  - Challenge due to its small x-section
- Decay modes:
  - For m_H > 135 GeV/c² H → WW$^{(*)}$ dominates (BR : 0.91 @ 160 GeV/c²)

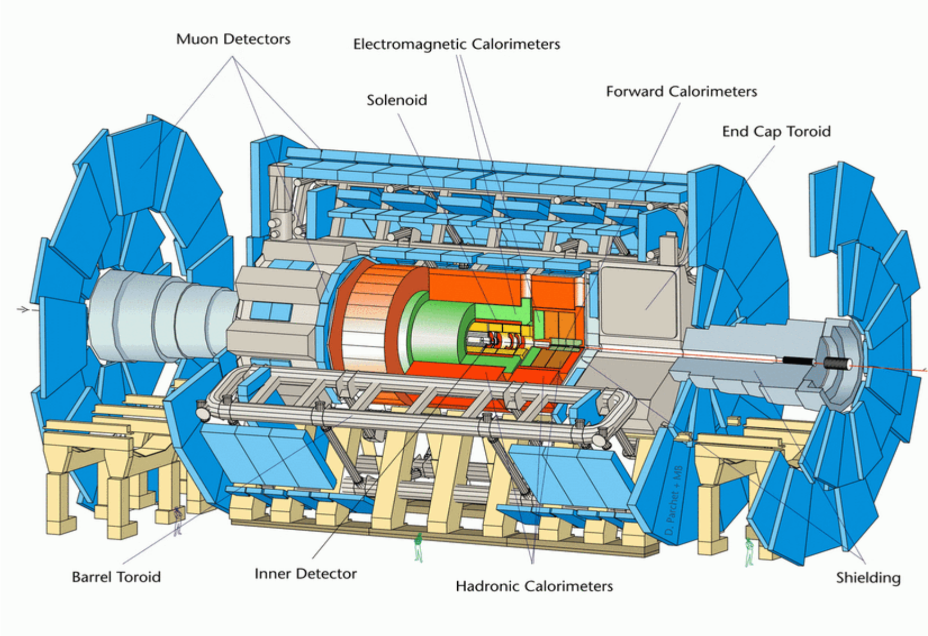
Difficult for this mass region: we need to associate more than one channel

The LHC and ATLAS

- LHC:
  - Proton-Proton collisions @ 14 TeV
  - First run @ 10 TeV expected fall 2009
  - Luminosity:
    - **Low luminosity regime ~$10^{32}cm^{-2}s^{-1}$**
      - **~ 200 pb^{-1} between 2009 and 2010**



- ATLAS:
  - General purpose experiments
  - Classic detectors composed mainly by 3 sub-systems
    - **Inner tracker**
    - **Calorimeter system**
    - **Muon spectrometer**
  - Very good Trigger/DAQ System
  - Good e/g/m/tau/missEt/b-jets identification

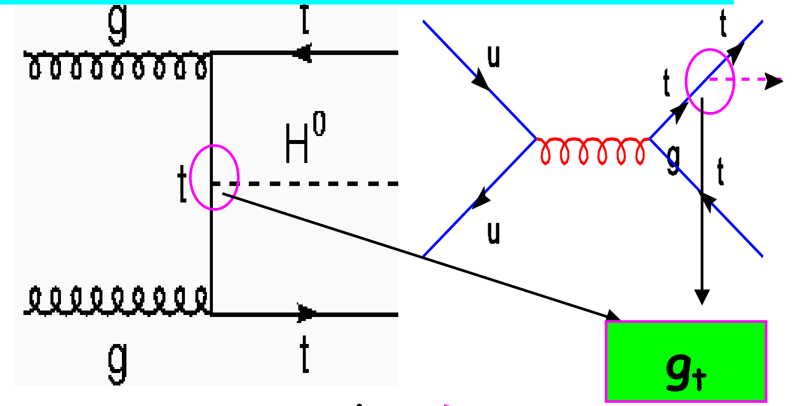


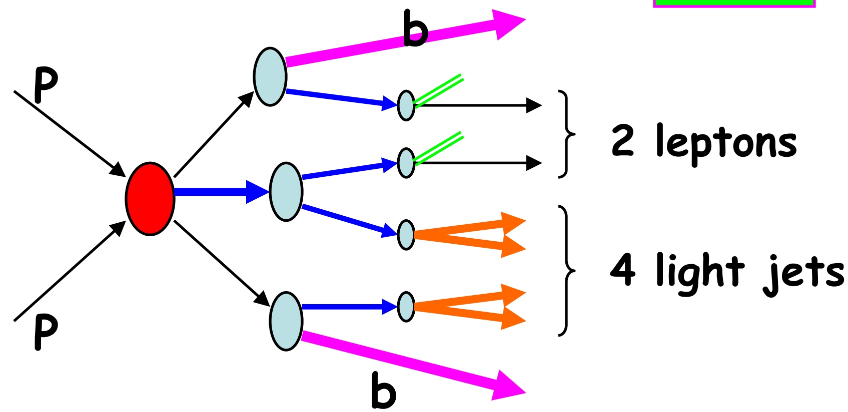
ATLAS detector

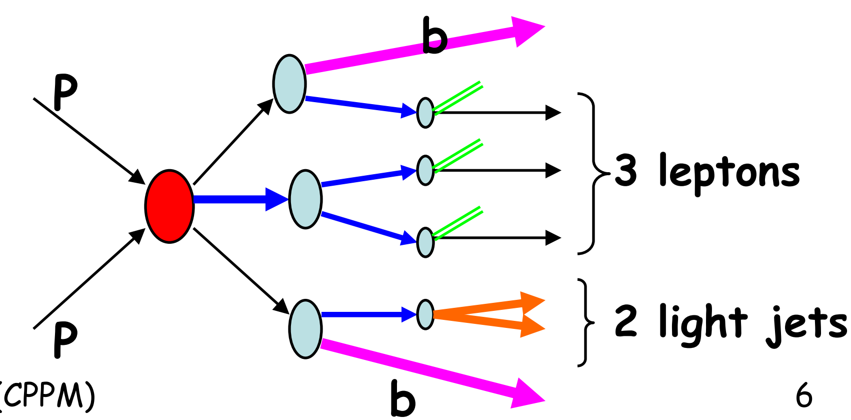
ttH,H→WW Signatures

- ttH→2b4j2l2ν_l
  - →6jets + 2samecharge lep. + MissEt
- Possible BKGs:
  - tt(1l), tt(2l), ttZ, ttW, tttt, ttWW, ttbb, W+jets, WZ+jets...
- ttH→2b2j3l3ν_l
  - →4jets + 3leptons + MissEt
- Possible BKGs:
  - tt(2l),ttZ,ttW,tttt,ttWW,ttbb

- tau not considered in signal
- Complex final states=>Number counting experiment
  - At least 2 neutrinos
  - Multi jets + Multi leptons + MissEt
- Background control important
- Main BKG tt suppressed by lepton isolation=>Lepton isolation is crucial
- ttZ suppressed by Z mass veto
- QCD BKGs under control







ttH,H→WW analysis @ 14 TeV

- One high Pt Isolated lepton trigger
  - Eff: 82% (2L),91% (3L)
  - offline significance impact < 1%
- Phys. Obj. kinematic region:
  - $|\eta|<2.5$; Pt>15.GeV
- Electron identification: Eff:70.5%
  - Calorimeter seeded Alg.
  - Matching to ID track
- Muon identification: Eff:92.7%
  - Seeded in Muon Spectrometer
  - Combined with ID track

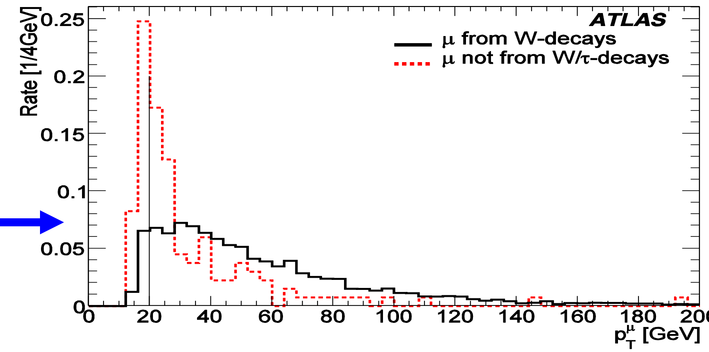
	σ[fb]	2L sel.	3L sel.
ttH2l	10.49	1.85±0.03	-
ttH3l	6.91	0.24±0.01	0.82±0.02
ttbar	833000	7.4±1.1	2.06±2.06
ttW+nj	582	1.7±0.06	0.47±0.04
ttZ	1090	1.14±0.07	0.86±0.06
ttbb	9100	0.55±0.18	-
tttt	2.68	0.07±0.01	-

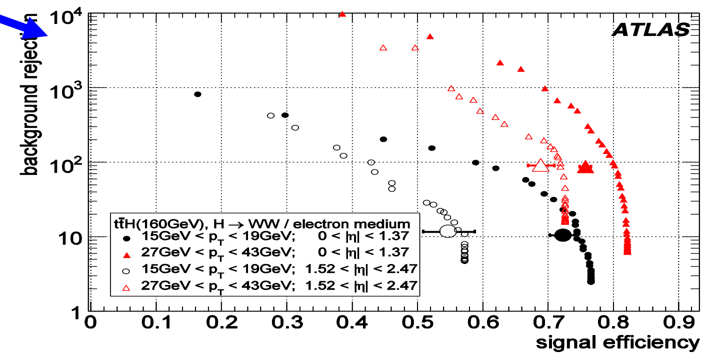
- Jet identification: cone based, size 0.4
- Lepton Isolation:
  - Electron:
  - Muon:

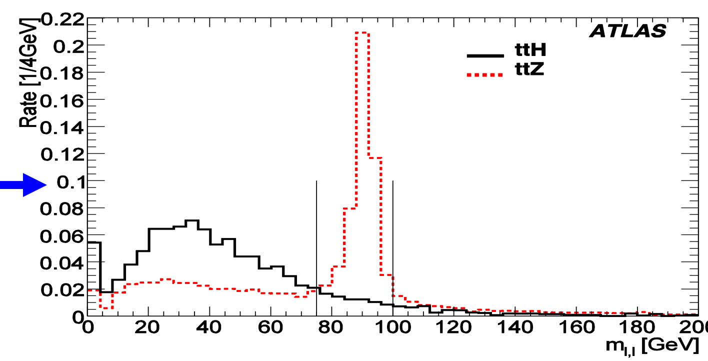
  Calorimeter Isolation_ + Tracker Isolation_ + Cone Isolation_
- Number of leptons >= 2/3, Number of jets >= 6/4
- Final tighten cut:
  - Zveto, MuonPt>20GeV, Number of lepton==2/3, sameCharged/null
- Possible Improvements using MV technic
  - Mass Constrained fit (good pre. Results, further study needed)
  - Isolation likelihood (good results shown)

ttH,H→WW Background rejection

- ttbar, single top, QCD+jets,
  - Fake/promote lepton from jets dominate the contribution for ttH BKG
  - Isolation methods developed to suppress fake/promote leptons
  - Higher lepton Pt further suppress fake/promote lepton
  - LLH method on isolation possible improve isolation performance
  - Same charge lepton requirement suppress ttbar 2l final states dramatically
  - High jets multiplicity help to suppress their contribution
  - BKG not include top can further suppress by partial reconstruction/construction of ttH system method (ex. Constrained fit, need further studies, not in CSC note)
- ttW
  - Not too big production cross section compared to signal
  - Very similar signature as signal => Second dominate BKG
- ttZ
  - Dedicated Z mass veto greatly suppress the contribution from BKG have a Z
- Other possible fake BKG ==> need Data driven method to estimate







Experimental uncertainties @ 14 TeV 30fb^{-1}

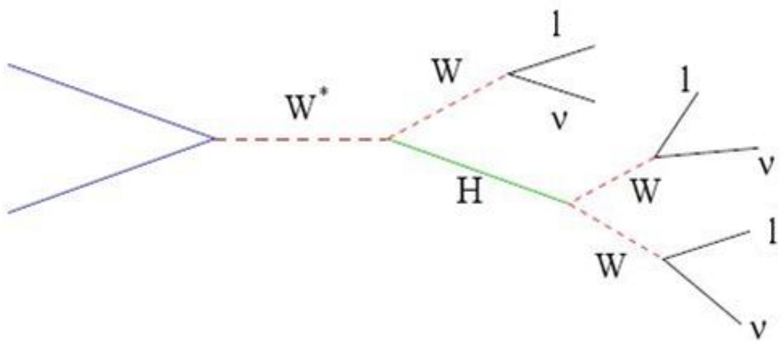
- The expected cross section for signal and backgrounds are:
  - 1.9:10 (fb)for ttH(2L) and 0.8:3.4 (fb)for ttH(3L)
- Several experimental systematic uncertainties are considered, based on current understanding of detector
- The main contribution of uncertainties are from JES

Source of the uncertainty		ttH (2L)		ttH (3L)	
		Δ signal (%)	Δ background (%)	Δ signal (%)	Δ background (%)
Luminosity	3	3	3	3	3
Electron ID efficiency	0.2	0.2	0.2	0.3	0.3
Muon ID efficiency	1	1.0	1.0	1.5	1.5
Electron E_T scale	0.5	0.1	0.1	0.2	0.3
Muon E_T scale	1	0.5	0.2	0.7	1.0
Electron E_T resolution		0.1	0.1	0.1	0.2
Muon p_T resolution		0.6	2.2	0.3	0.9
Jet energy scale	7	1.2	4.9	2.7	10
Jet energy resolution		1.0	1.4	1.9	5.7
Electron isolation efficiency	1	1	1	1.5	1.5
Muon isolation efficiency	1	1	1	1.5	1.5
Experimental uncertainty		±3.9	±6.6	±5.2	±12.3

Using early data to understand these systematics

WH,H→WW Signature and selection

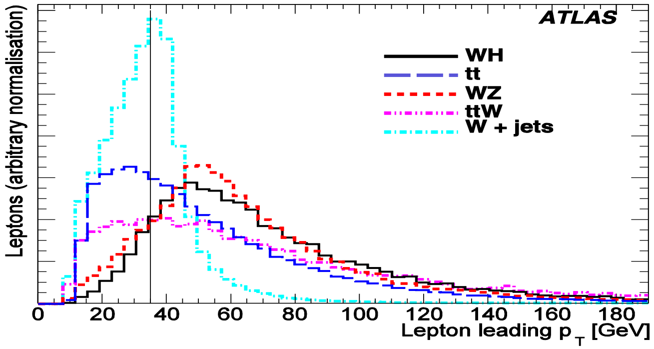
- Higgs physics
  - Supplement to the Discovery
  - Necessary confirmation for the property
    - Couplings to gauge boson
- WH,H→WW$^{(*)}$ physics analyses
  - One High Pt isolated lepton trigger
  - Two and three lepton final states (2L/3L)
    - WH→WWW$^{(*)}$→lv lv jj (under investigate, not in this report)
    - WH→WWW$^{(*)}$→lv lv lv
  - Full analysis over WH against ttbar, WZ, ttW, ZZ
  - Number counting experiments



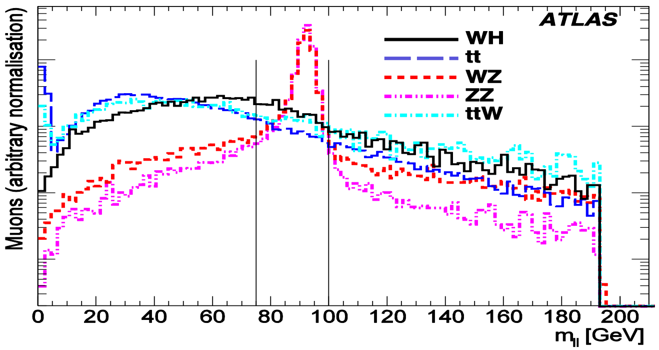
- Number of jets and leptons
- Zveto
- Missing Transverse Energy
- Lepton isolation
  - **Calorimeter isolation**
  - **Tracker isolation**
  - **Cone isolation**
  - **Impact parameter**
- B-jet/jet veto
- W mass range
- Higgs-Spin cut

WH,H→WW Background rejection

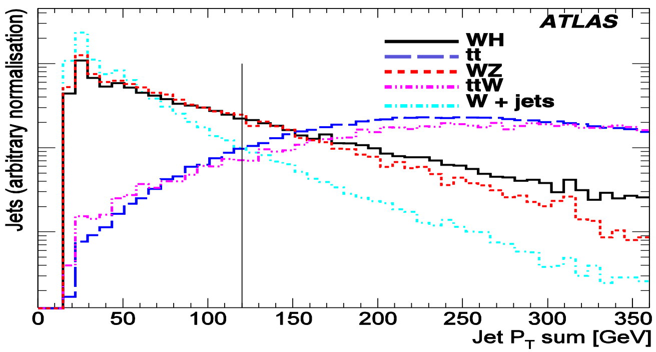
- *pT*-distribution for the leading leptons in the *WH*(3*L*) signal, *ttbar*, *WZ*, *ttW* and *W*+jet production



- Zveto to suppress the contribution from BKG have a Z
  - invariant mass of all the lepton pairs



- B-jet/jet veto
  - sum of the *pT* of all jets
  - No B-tagged jets



Experimental uncertainties @ 14 TeV 30fb^{-1}

- The expected cross section for signal and backgrounds are:
  - 0.3:0.4 (fb)
- Several experimental systematic uncertainties are considered, based on current understanding of detector
- The main contribution of uncertainties are from JES

fb	WH3L	WZ	tt	ZZ	ttW	wbb	W+jet
σ	3.42	44760	833000	14750	582	2.1*10^5	1.9*10^8
3L selection	0.31	0.10	0.34	0.005	0.003	0	0

Source of the uncertainty		*WH* 3L selection				
		Δ *WH* (3L) (%)	Δ *WZ* (%)	Δ $t\bar{t}$ (%)	Δ *ZZ* (%)	Δ $t\bar{t}W$ (%)
Luminosity	3	3	3	3	3	3
Electron ID efficiency	0.2	0.3	0.3	0.2	0.9	1.1
Muon ID efficiency	1	1.5	1.7	1.9	1.0	1.7
Electron energy scale	0.5	0.06	0.06	0.2	0.02	0.07
Muon energy scale	1	0.2	0.1	1.0	0.08	0.7
Muon p_T resolution		0.1	0.03	0.2	0.02	0.4
Jet energy scale	7	2.5	2.6	17.4	2.3	13.6
Jet energy resolution		0.005	0.03	1.9	0.5	0.7
b-tag eff. / light jet rej.	5 / 32	1.0	1.0	2.7	0.8	3.2
Experimental uncertainty		±4.3	±14.5			

ttH/WH,H→WW$^{(*)}$ strategy for real data

- 200bp^{-1} data @ 10 TeV (preparation and BKG estimation)
  - Not possible for signal identification (too small X-section)
    - 2.2 signal expected to be produced(0.4 to be observed) for ttH,H→WW 2lepton channel
  - BUT understanding detector performances and Background level is crucial with early data:
    - Performance involved:
      - trigger; electron, Muon, Jets, BJets, Missing Et
    - Detects involved:
      - ID, Calo, Muon
    - Several Data driven method to estimate backgrounds level are under investigation, tool need to be prepared and tested with first data (see backup)
  - Limit on $\sigma_{ttH/WH}$ * Br_H→WW can be given for given higgs masses
  - However similar signature of SUSY same charge dilepton channel searches share the same BKGs of ttH2L (CPPM/IHEP) accessible with early data

- ~30fb-1 data @ 14TeV is more feasible for ttH/WH,H→WW analysis, while many of the performance should be consistent with 10 TeV ➔ study the first data for these channels crucial

Summary and prospects

- ttH,H→WW $^{(*)}$ and WH,H→WW $^{(*)}$ studies done with ATLAS real detector geometry full simulation, under IHEP(China) and CPPM(France) cooperation, each channel is in a co-tutor Ph.D thesis and in the Higgs CSC(HG6) publication
- Contribute to coupling measurement
  - ttH,H→WW $^{(*)}$ (gt)
  - WH,H→WW $^{(*)}$ (gW)
- Number counting experiments => BKG control is crucial
  - Mass peak reconstruction:
    - **Hopeless in ttH,H→WW$^{(*)}$, not yet tried in WH,H→WW$^{(*)}$**
  - Background uncertainties using early data
    - **JES dominate the uncertainties of BKGs**
    - **BKG normalization/estimation important**
    - **Data driven method needed**
    - ***More advanced methods during 30fb^{-1} data gathering***
    - ***Statistical part of systematic uncertainties reduced with 30fb^{-1} data***
- Improvement of these analysis ongoing
- China France cooperation fruitful to get best results of first data

Bak up: Main Issues for ttH/WH,H→WW$^{(*)}$ Channel

- Higgs reconstruction difficult
  - At least two neutrinos, one from Higgs W decay, one from top W decay
  - With a virtual W, which could decay leptonic or hadronic
  - Large combinatory in complex final states
- Lepton isolation is crucial in background suppression
  - Several isolation methods are tried
  - Could improve by Multivariable methods, with better understanding of real data
- Big uncertainty for the backgrounds cross section normalization
  - Theoretical uncertainties could improve with understanding of real data
  - Need data driven methods to estimate BKG
- Data Driven methods to estimate BKG level are under development

ttH/WH,H→WW analysis data driven strategy (1)

preliminary

ttH-WW* BKG Fraction

	S/B	ttbar	ttW	ttZ	Sum.
ttH2L	**0.16**	**62%**	**17%**	**13%**	**92%**
ttH3L	**0.22**	**55%**	**15%**	**29%**	**99%**

The X and Y variable should have large discrepancy

- **ideal case, they aren't correlate**
- **different bg sources are estimated separately if their shapes differ in these variables**

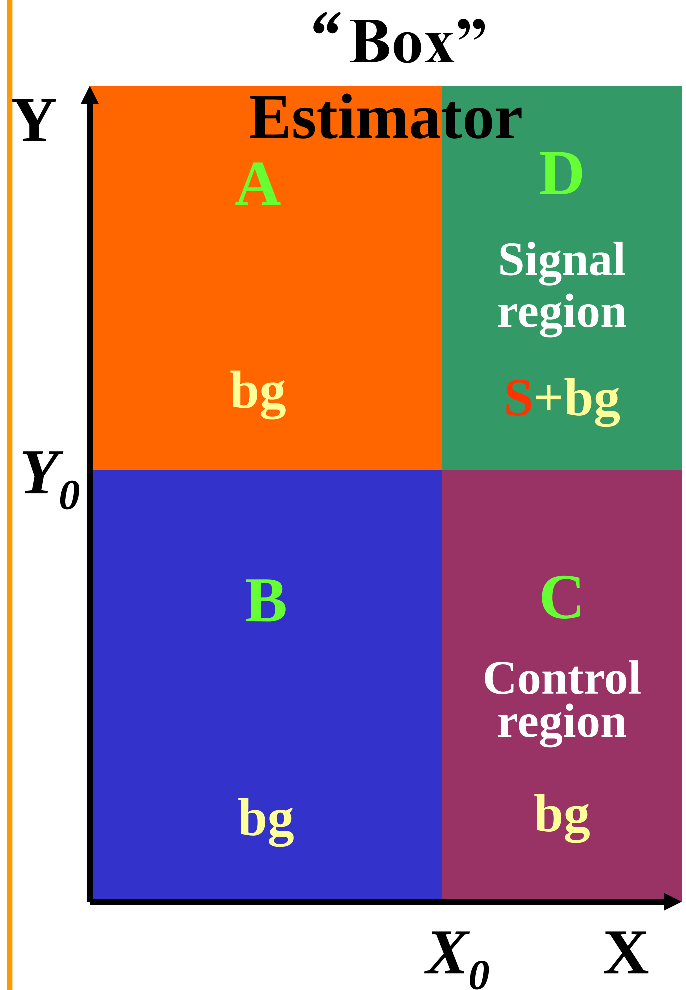
A/B = D/C , D=A*C/B

(A+B)/B = (C+D)/C, (C+D) = (A+B)*C/B

In real data A,B,C are obtained from controlled ttbar pure sample;, ttH-WW selected D includes S+bgs, then bg from ttbar can be calculated from A,B,C numbers.

First try using N_lep and N_lightjets to check their correlation, more variables investigation needed

Similar strategies for ttW, ttZ bg estimation



ttH/WH,H→WW analysis data driven strategy (2)

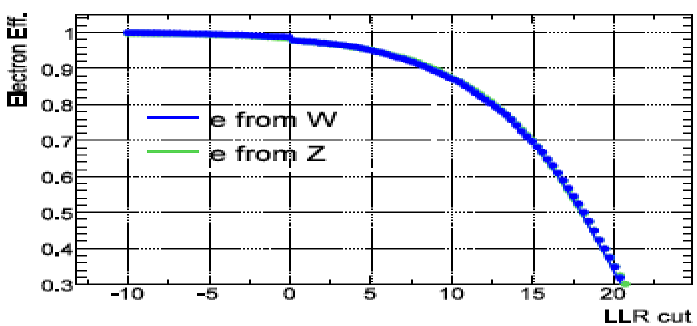
preliminary

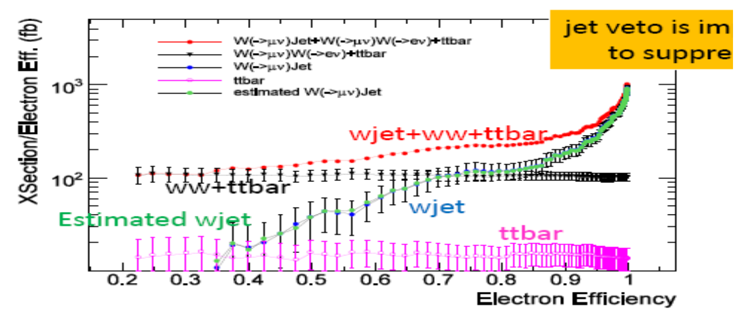
- Category BKG into several sources
  - Charge Flip (ttH,H→WW 2L only)
  - Z+x and W(→l v)+x, where x can be top/W/Z, who can have a isolated lepton in the final states
  - Non-isolated/Fake lepton
  - …
- Lepton charge flip BKG estimation
  - Using Z→ee/uu control sample to estimate the charge flip rates
  - Using charge discrepancy of Muon system and ID system control sample (ttbar, Z->uu…), to estimate ID charge flip rates (suppose Muon system charge flip rates lower than ID)
- Z+x and W+x background estimation ?
  - Back to strategy 1?
  - Ideas are extremely welcome (zhang@cppm.in2p3.fr)

ttH/WH,H→WW analysis data driven strategy (2)

preliminary

- Non isolated lepton BKG estimation
  - $\sigma_{x-channel} /(Eff_{lep1\_iso} * Eff_{lep1\_iso})$ should be const if x-channel do have 2 isolated lepton and Efflep1_iso and Efflep2_iso do present the lepton isolation efficiency, while it will change if one of the lepton is not isolated
  - The data is a mixture of channel which have 2 isolated lepton and at least 1 non-isolated lepton, a asymptotic fit to get the const term and the changing term, and the changing term curve represent the non isolated lepton contributions
  - Similar method has been used in H→WW analysis to estimate fake BKG from W+jets, the results seems promising





  - Using a lepton isolation variable (EtCone,LLH…), to estimate prompt (non-isolation) lepton background instead of using Lepton ID
  - Using ttbar control sample to determine Lepton Isolation efficiency vs criteria curve (tried in CSC 30fb-1 MC, not in the pub note yet)
  - Tool preparation and initial studies needed…