The Channel WH, H-> bb at Large Transverse Momenta in ATLAS

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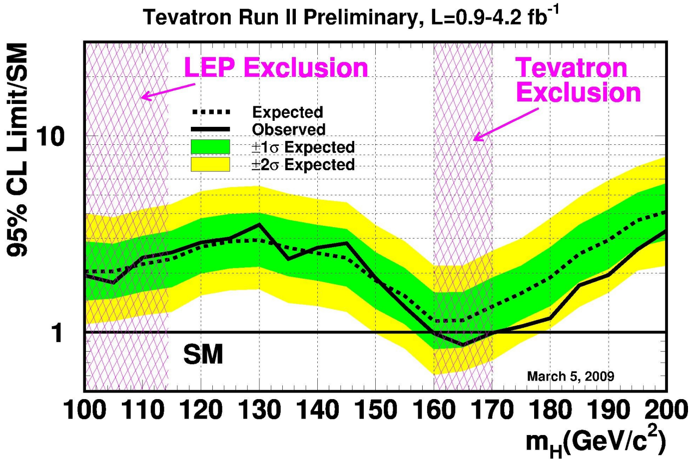
- Introduction
  The SM Higgs Boson at low masses

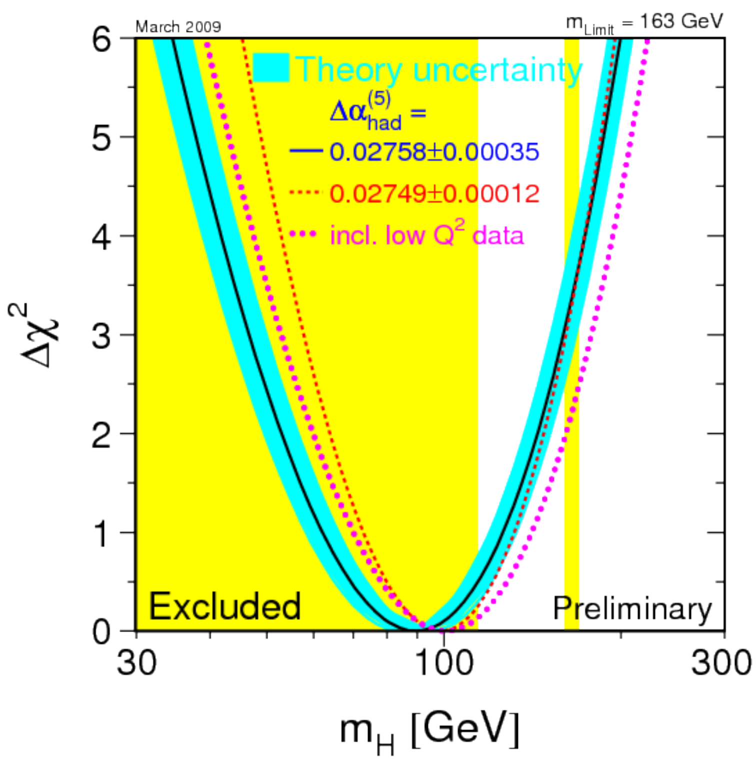
- WH at high transverse momenta:
  - Topology
  - Jet Clustering
  - B-Tagging
  - Results (+ ZH)

- Summary

ATLAS Note:
ATL-PHYS-PUB-2009-088

What do we already know?





- Direct searches at LEP

M_H > 114.4 GeV/c² (95% CL)

- Direct searches at the TEVATRON

Exclude 160 GeV/c² < M_H < 170 GeV/c² (95% CL)

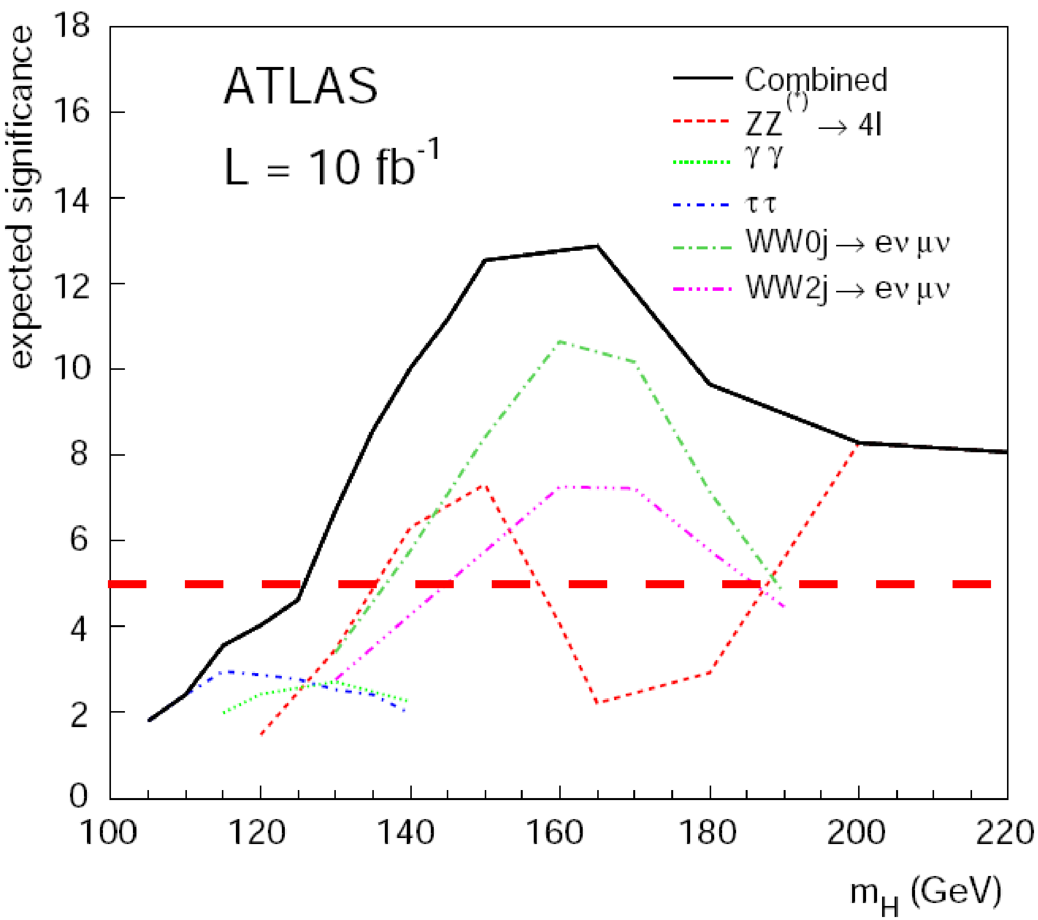
- electroweak precision measurements

M_H < 163 GeV/c² (95% CL)
(191 GeV/c² incl. LEP Limit)

If we believe in the SM and these measurements:
Light Higgs boson preferred

Low Mass Higgs Boson

Discovery Potential from ATLAS CSC book



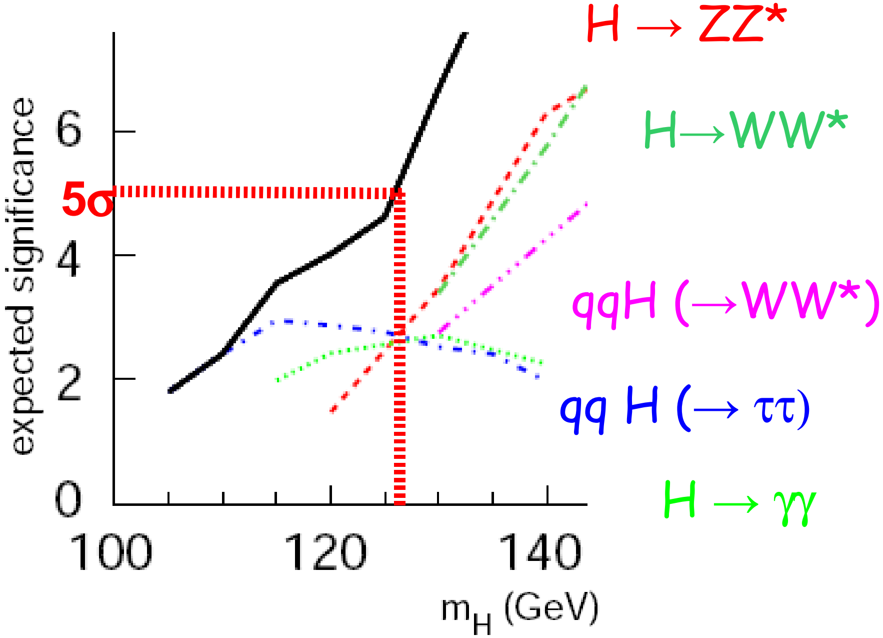
Low masses close to LEP limit

$H \to \gamma\gamma$

VBF $H \to \tau\tau$

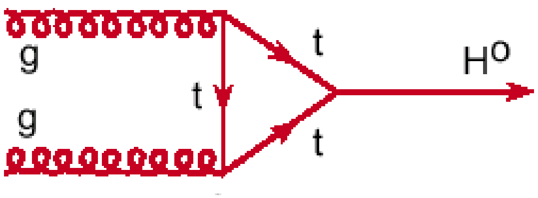
Challenging!

- Additional information welcome!
- look for H-> bb decay

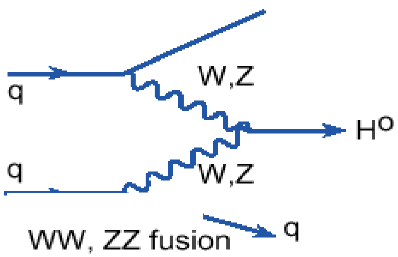


Higgs Boson Production & Decay

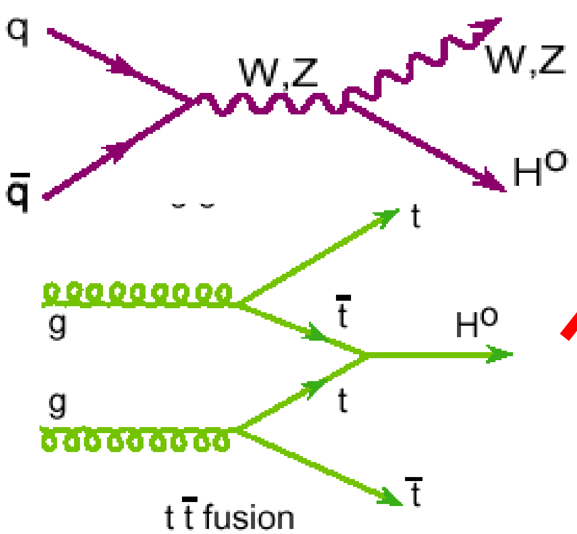
(i) Gluon-Fusion

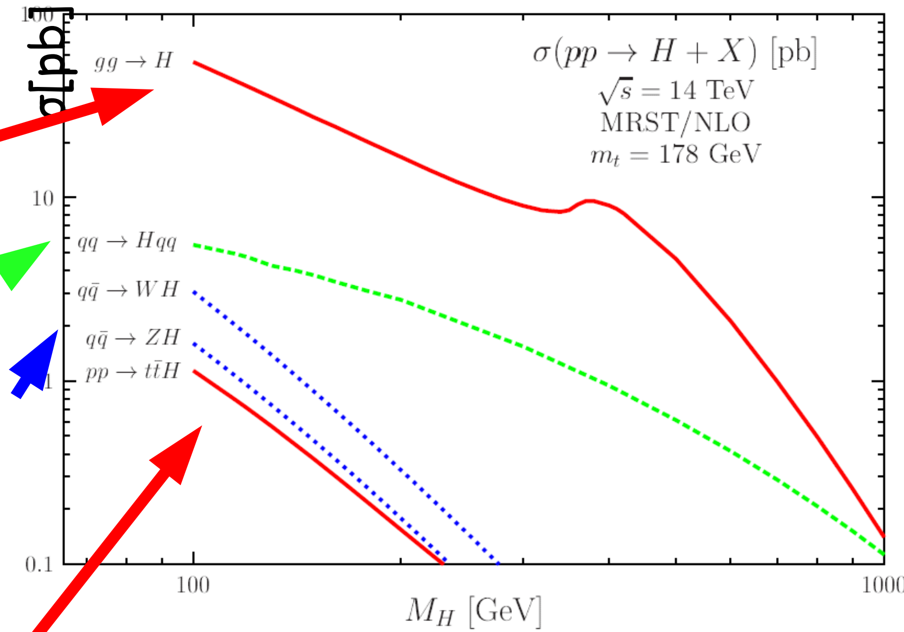


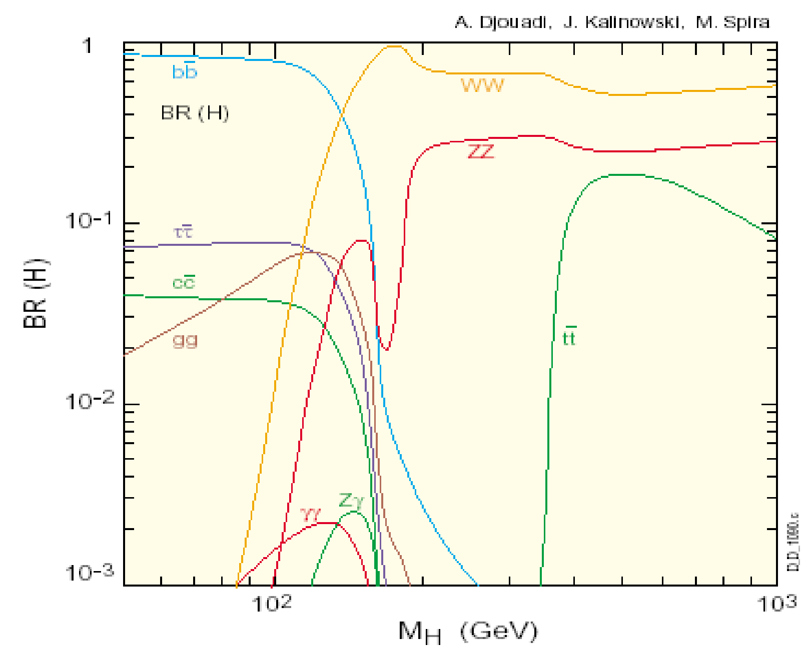
(ii) Vector Boson Fusion (VBF)



(iii) Associated Production (W/Z, tt)

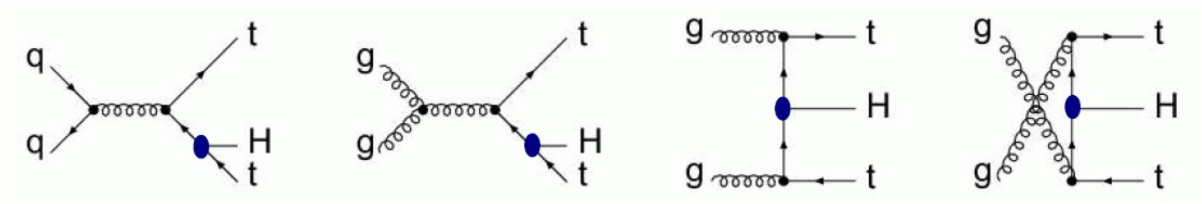


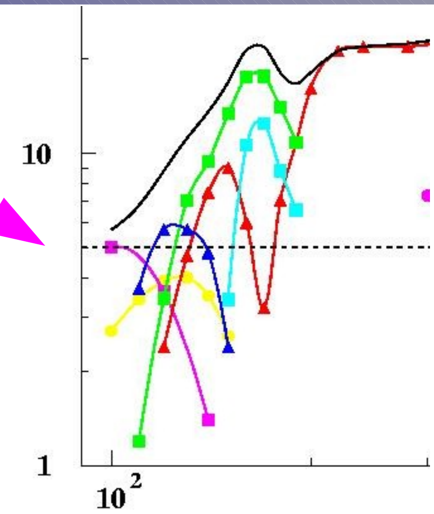




What about ttH, H → bb ?

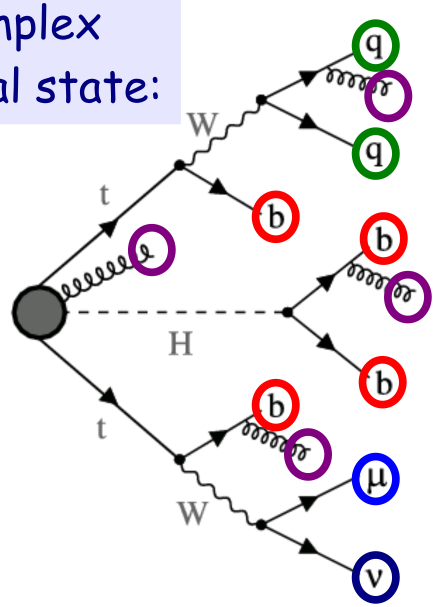
a promising search channel some years ago:



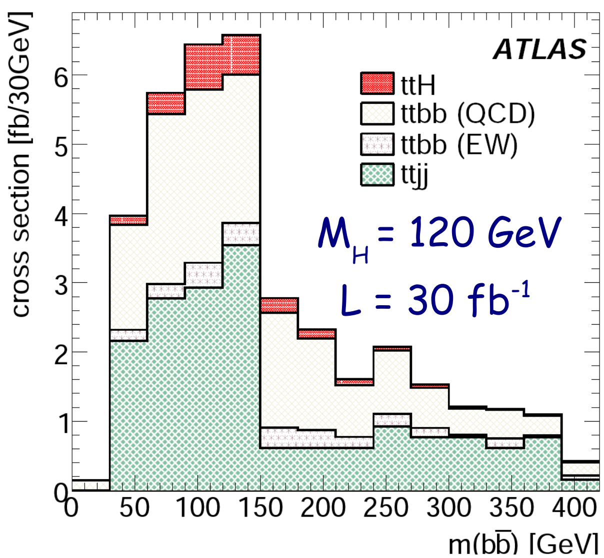


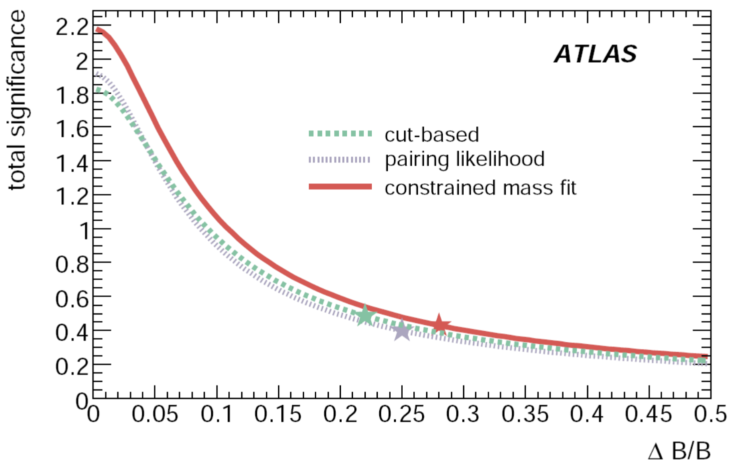
Access to top-Higgs Yukawa coupling!

Complex final state:



Now:





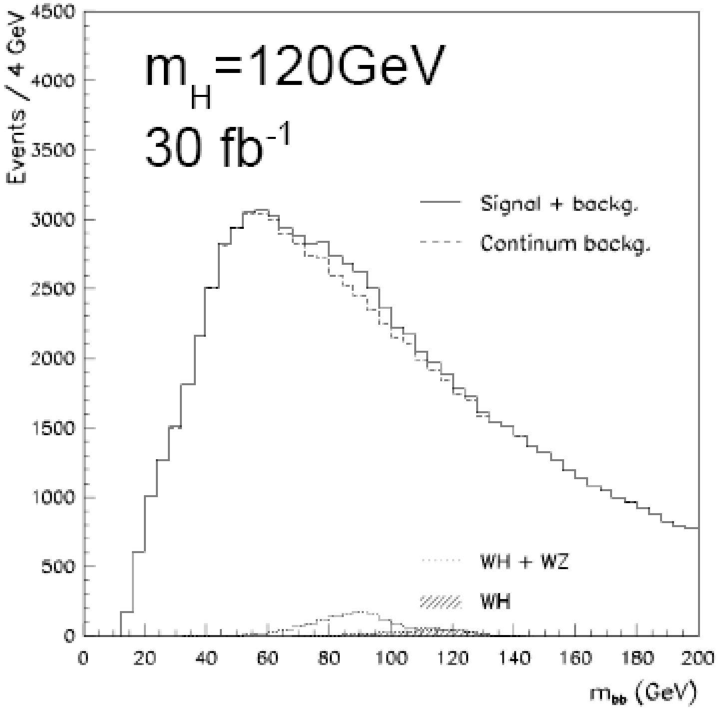
Main Backgrounds:
ttbb, ttjj

- Need extremely precise background normalization!
- Has to come from data!

→ ttH has disappeared from latest sensitivity plots!

The Channel WH, H->bb

History:



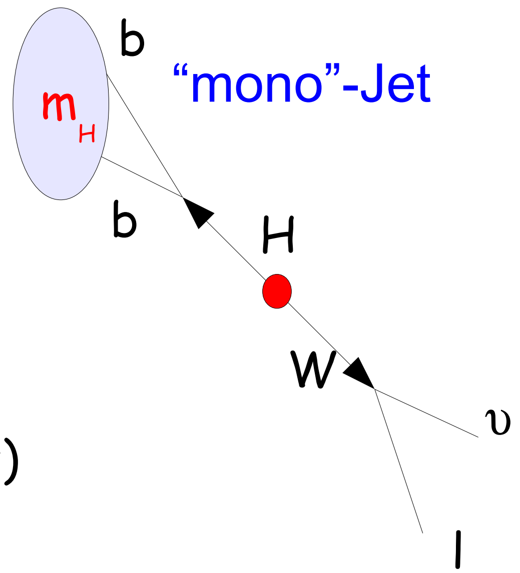
$S/\sqrt{B}$	2.1
S/B	1.3%

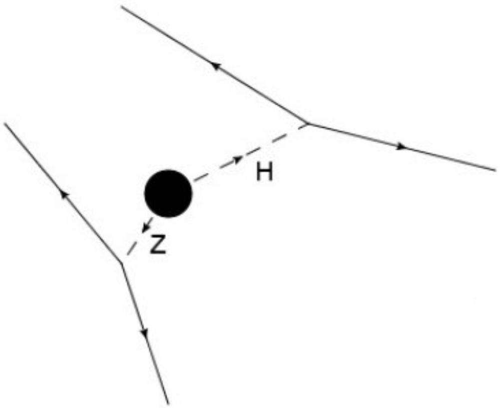
Very difficult because of low signal to background ratio
-> not considered as serious search channel at the LHC
(but: main search channel for low masses at the TEVATRON!)

WH

Follow idea of J.Butterworth et al. [PRL 100:242001,2008]:

Select events in which H and W bosons Have large transverse momenta: p_T > 200 GeV (≈5% of total x-sect.)



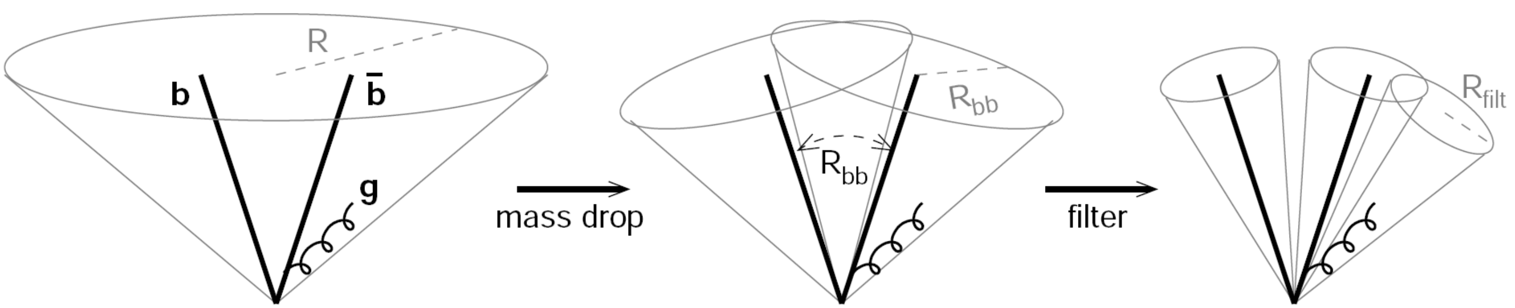


-> b quarks in one "fat" jet

+ strong reduction of backgrounds (e.g. tt)
+ acceptance (more central in detector)
+ good kinematical range for lepton identification and B-Tagging

Backgrounds considered:
tt, WZ, W+jets, single top Wt

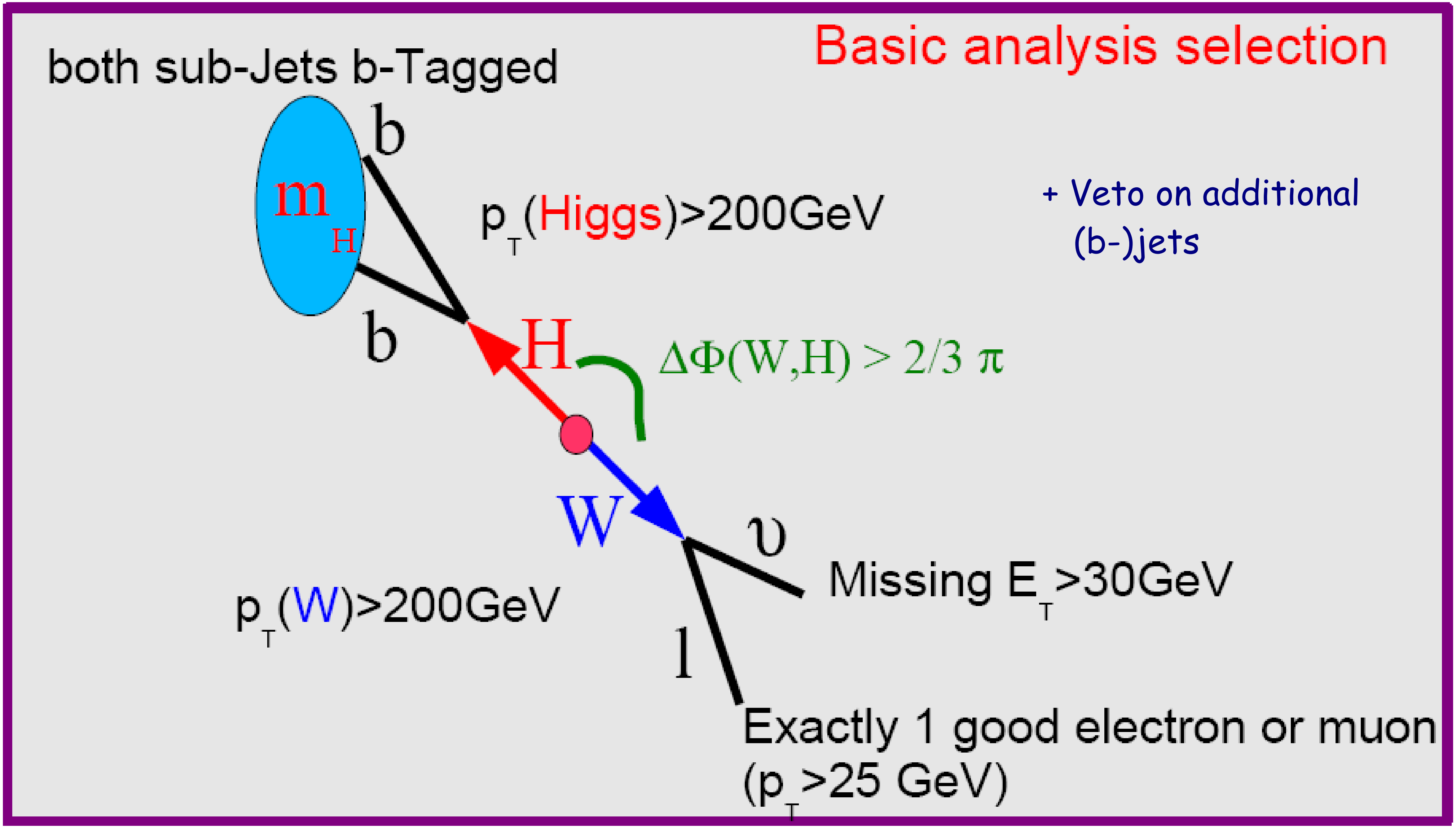
Analysis of jet (sub)structure:



MC, Samples, Simulation

- For all processes: LO Monte Carlo (HERWIG, AcerMC + PYTHIA for Wt) and LO cross sections
- >10M simulated events needed
- Fast detector simulation **ATLFAST-II** used for the simulation of all samples:
  - **Full simulation of the Inner Detector + MuonSystem** (crucial to reproduce correctly b-tagging performance)
  - **FastCaloSim** for calorimeter response (full granularity needed to reproduce subjet clustering correctly)
- No Pile-Up simulation included (yet).
- **Validation of AtlFast-II:**
  - Cross checks performed to test ability of AtlFast-II to reproduce detailed subjet clustering structure in boosted $H \rightarrow bb$ (using WH signal Monte Carlo). (+ extensive validation done by fast simulation team)

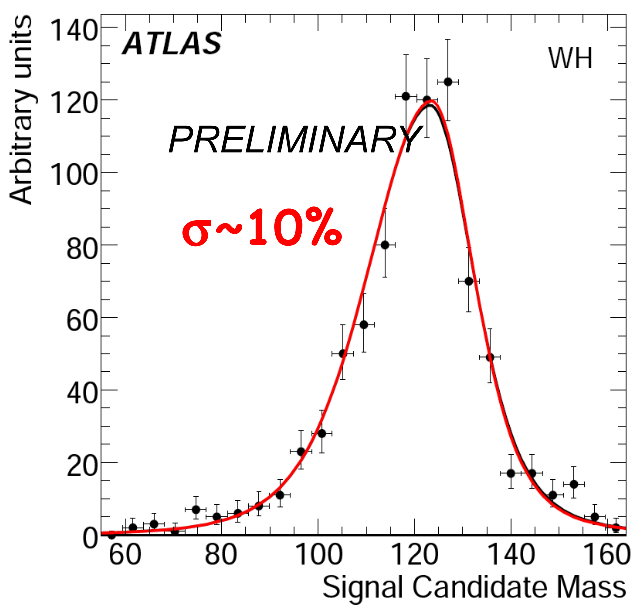
WH: Analysis


Basic analysis selection
both sub-Jets b-Tagged
b
m_H
b
p_T(Higgs)>200GeV
+ Veto on additional (b-)jets
H
ΔΦ(W,H) > 2/3 π
W
υ
Missing E_T>30GeV
p_T(W)>200GeV
l
Exactly 1 good electron or muon (p_T>25 GeV)

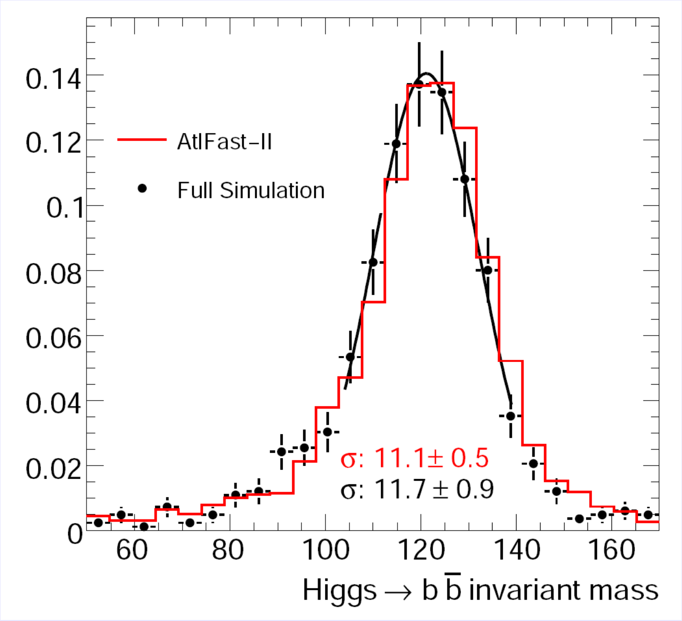
Mass Reconstruction

B-jet energy calibration:

- Add muons from semileptonic b-decay (no correction for neutrino)
- Dedicated p_T dependent calibration

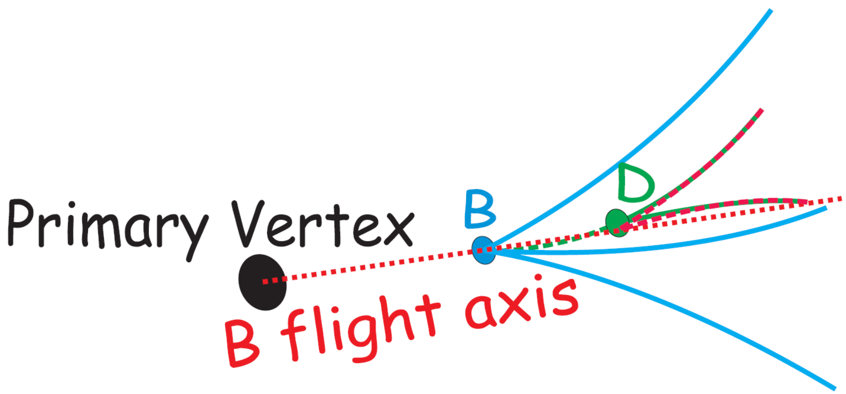


Comparison full vs. fast simulation:
Apart from small shift in the energy scale, subjet structure well reproduced!

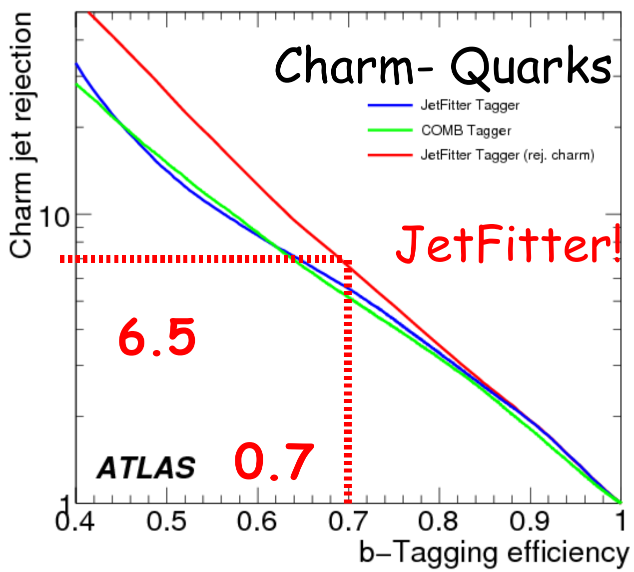


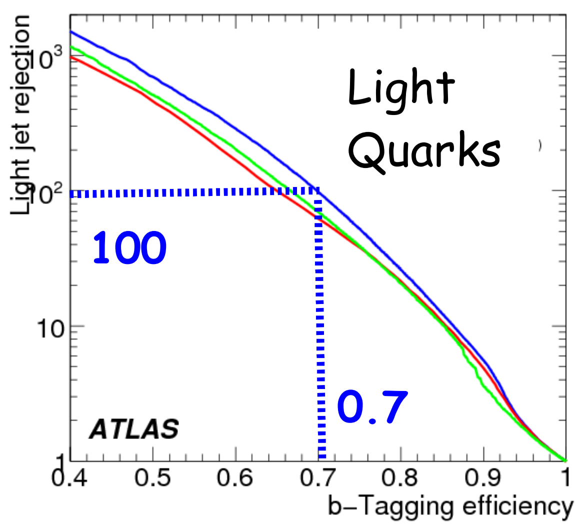
B-Tagging

Apply ***JetFitter*** algorithm:
- -b and c vertices lie approximately on same line of flight
- -allows for full fit of complete decay chain (Kalman filter implementation)
- -topologies accessible that are missed by "classical" secondary vertex finding algorithms



JetFitter performance on filtered subjets

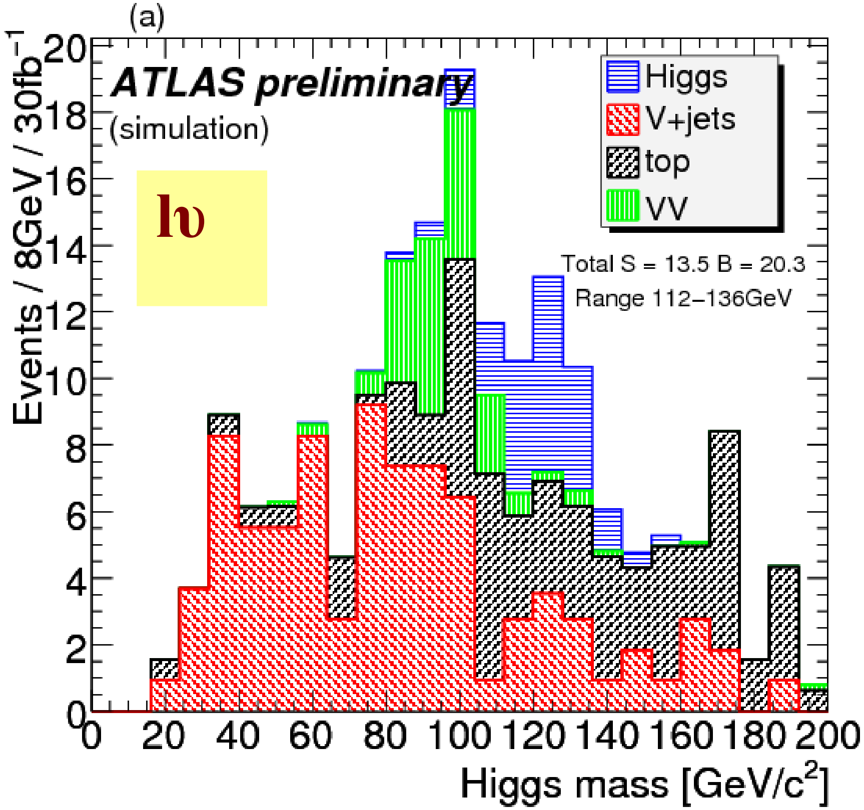




Dominant background from tt:
- 1 real b jet +
- 1 c jet from W decay

→ c rejection important!

WH: Results

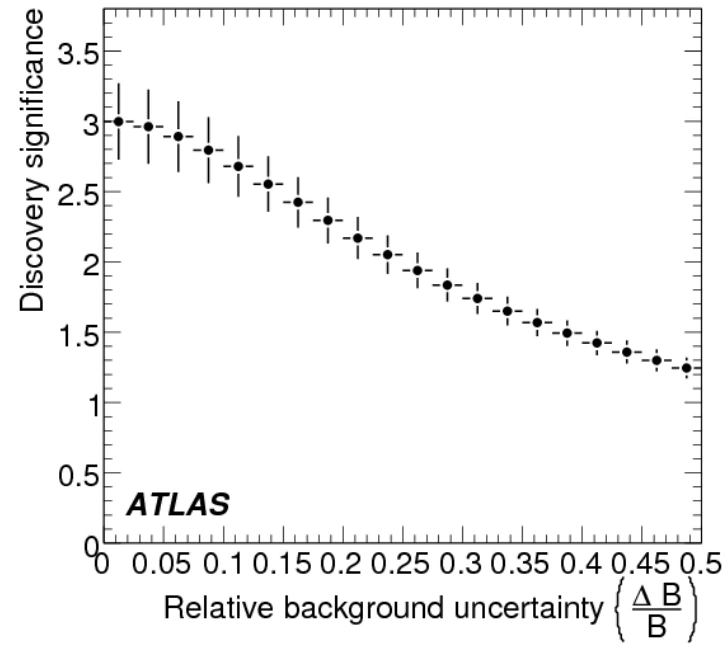


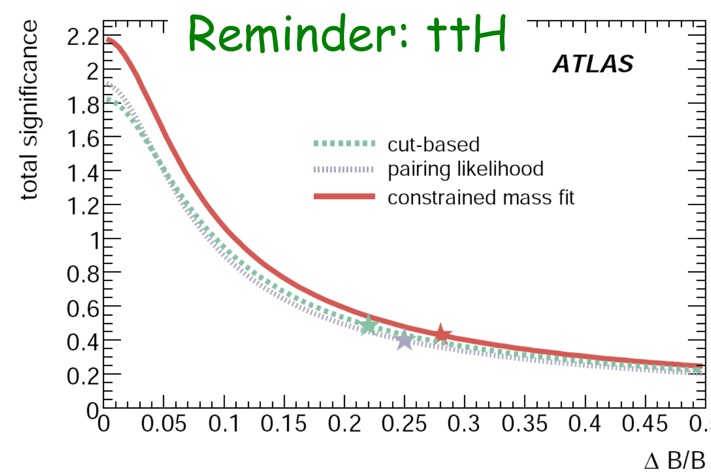
M_H = 120 GeV

$$L^{int.} = 30\ fb^{-1} : \frac{S}{\sqrt{B}} = 3.0 \pm 0.3$$

S/B ≈ 2/3

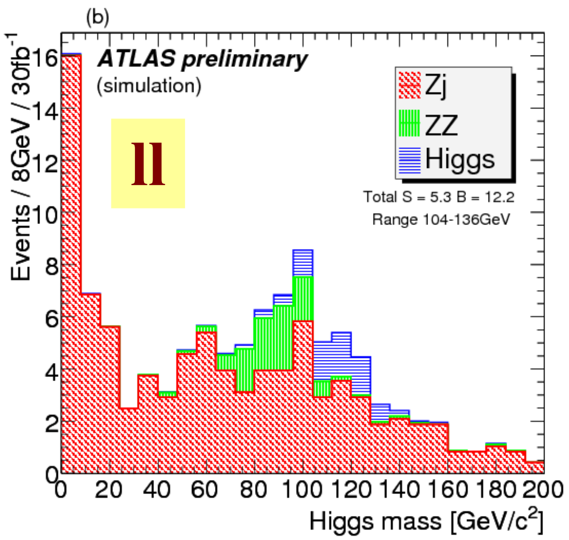
Background uncertainties:



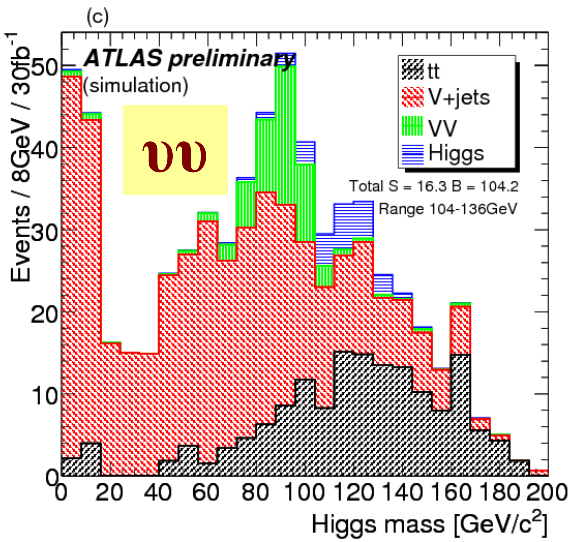


ZH and Combination

ZH, with Z->ll oder Z->νν
(performed by A. Davison, UCL)



$$\frac{S}{\sqrt{B}} = 1.5$$



$$\frac{S}{\sqrt{B}} = 1.6$$

Channel	s_i	t_i	w_i	z_i	$S/\sqrt{B}$
$llb\bar{b}$	5.34	0.98	0.0	11.2	1.5
$l\nu b\bar{b}$	13.5	7.02	12.5	0.78	3.0
$\nu\nu b\bar{b}$	16.3	45.2	27.4	31.6	1.6
Combined					3.7

σ_t	σ_w	σ_z	Significance
Perfect	Perfect	Perfect	3.7
5%	5%	5%	3.5
10%	10%	10%	3.2
15%	15%	15%	3.0
20%	20%	20%	2.8
30%	30%	30%	2.5
50%	50%	50%	2.2

Combined:

$$\frac{S}{\sqrt{B}} = 3.7$$

- S/B much better than for ttH
- Different backgrounds for different channels
- Still good sensitivity including systematics
  (e.g. S/√B = 3.0 for 15% uncertainty on all backgrounds)

Conclusions

- New hope for the decay mode $H \rightarrow bb$ in the associated production channel WH (and ZH)

- Important for:
  - Confirmation of discovery in other channels
  - Access to b coupling

- Outlook:
  Fit based approach based on data control samples
  + full estimate of systematic uncertainties

BACKUP

WH Cut Flow

L=30 fb^{-1}

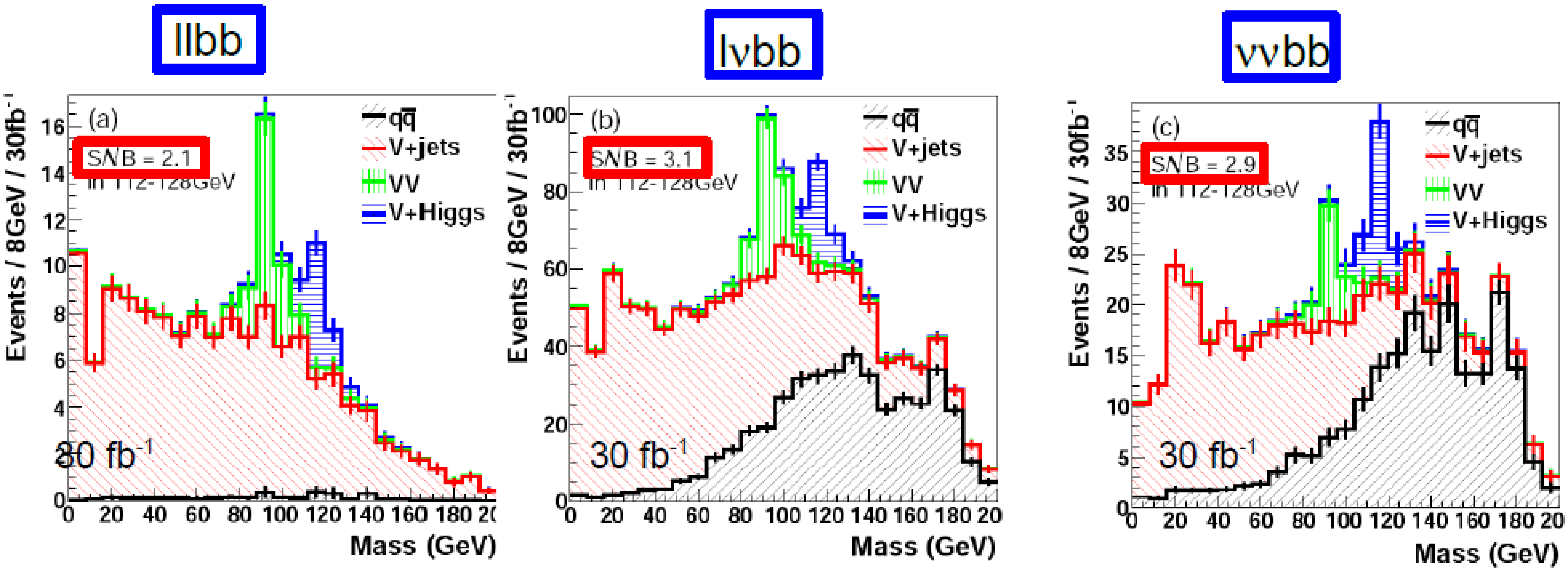
	WH(120)	WZ	$t\bar{t}(p_T^{min})$	Wt	W+jets
After filter cuts	1252.8 ± 7.8	9331	1609356	169519	2433885
1 Higgs candidate	569.7 ± 3.0	3509.7 ± 8.0	806175	69375	562030
filtered $p_T > 200$ GeV	512.7 ± 3.2	3108 ± 10	709271	60241	413406
Missing $E_T > 30$ GeV	362.4 ± 3.2	2183 ± 13	552284	46779	318400
p_T(W) > 200 GeV	171.0 ± 2.6	1216 ± 12	137946	18524	206331
$p_T(e/\mu)$>30 GeV	145.6 ± 2.4	996 ± 11	115053	15724	178004
p_T(additional μ)<10 GeV	144.6 ± 2.4	942 ± 11	106836	14992	177542
p_T(additional e)<10 GeV	142.9 ± 2.4	885 ± 11	97305	13881	174941
$\Delta\phi$(W,H) > $\frac{2}{3}\pi$	142.2 ± 2.4	841 ± 11	84773	12999	167704
no additional b-jets p_T >15 GeV	130.6 ± 2.3	790 ± 10	30605	7805	160608
add. jets on W side p_T <60 GeV	115.7 ± 2.2	637.2 ± 9.5	19422	5870	121437
add. jets on H side p_T <60 GeV	102.7 ± 2.1	525.6 ± 8.8	13841	4370	94055
one subjet b-tagged	91.4 ± 2.0	126.1 ± 4.5	8638	2421	6964
both subjets b-tagged	45.6 ± 1.4	43.7 ± 2.7	576	161.4 ± 7.0	266
loose fit cuts	45.4 ± 1.4	43.0 ± 2.7	565	156.3 ± 6.9	257

	WH(120)	WZ	$t\bar{t}(p_T^{min})$	Wt	W+jets
add. jets on W side p_T <20 GeV	83.2 ± 1.9	461.3 ± 8.3	7227	3343	86087
add. jets on H side p_T <20 GeV	55.8 ± 1.6	275.6 ± 6.6	1895	1142	48229
one subjet b-tagged	46.4 ± 1.5	49.8 ± 2.9	986	498 ± 12	1825
both subjets b-tagged	19.51 ± 0.96	16.5 ± 1.7	38.9 ± 4.9	18.2 ± 2.4	87.3 ± 9.0
112 GeV < mass(H) < 136 GeV	13.25 ± 0.79	1.18 ± 0.45	5.6 ± 1.9	4.2 ± 1.1	8.3 ± 2.8

Result of hadron level study

[J. Butterworth, A. Davison, G. Salam, M. Rubin, PRL 100:242001,2008]

- Performed for three final states:

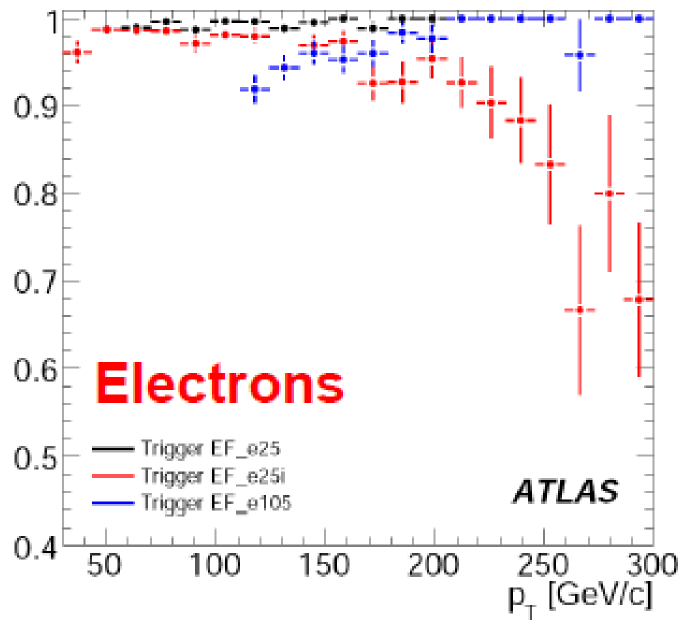


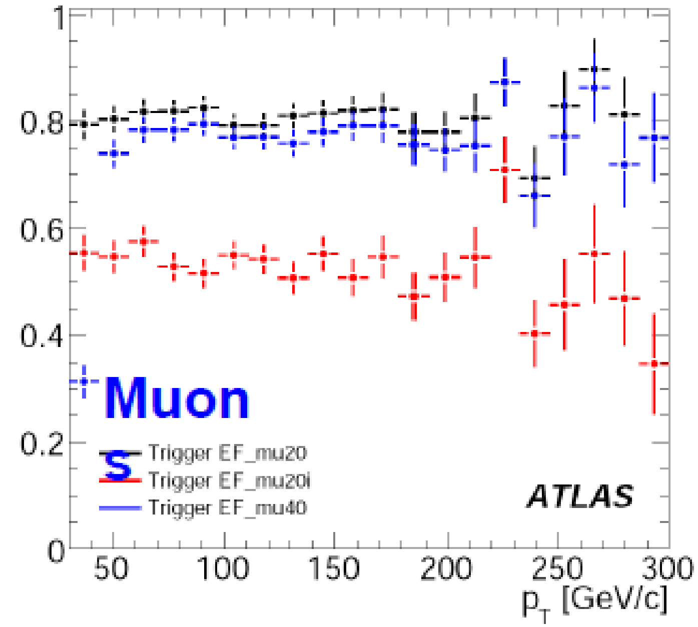
- Hadron level result:
  → combining the three channels, with 30 fb^{-1} a significance above 4 should be feasible.

- Most crucial experimental issues:
  - (1) realistic estimation of di-b quark invariant mass resolution
  - (2) it is assumed b-tagging works well on subjets. Does it really work?

Trigger efficiency (WH)

- Mostly trigger on high p_T lepton from W boson:





- WH channel:
  - Use combination of: mu20i+mu40+e25i+e105+J80_xe70
  - Muons outside L1 Trigger acceptance provide large MET: recover these events by MET + jet trigger !
  - Efficiency w.r.t. Offline: ~99.5 %
  - Trigger inefficiency (0.5 %) is negligible...