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Search for the MSSM H/A bosons decaying to two muons at ATLAS

- Production and decay of the MSSM H/A Higgs bosons
- Signal and background
- Analysis strategy
- Results
- Summary and conclusions

MSSM H/A production mechanisms

direct (H/A)

Main background is irreducible $Z/\gamma^* \rightarrow \mu\mu$ => the direct signal overwhelmed by the background.

Lower signal significance!

Look for different tanβ values

associated with bbar (bbH/A)

dominant for large tanβ

Main background: $tt \rightarrow (bW)(bW) \rightarrow \mu\mu$ and irreducible $Zbb \rightarrow \mu\mu$

ANALYSIS: efforts to isolate associated signal;

The cuts oriented in reducing ttbar background

Which scenario?

- M_h^{max} scenario has been followed (M. Carena, S. Heinmeyer, C.E.M. Wagner and G. Weiglin, “Suggestions for benchmark scenarios for MSSM Higgs boson searches at hadron colliders”)
- Adventage: maximizes the h mass ($M_h^{max} \leq 135$ GeV/c^2) with respect to tanβ and allows conservative tanβ exclusion limits.
- Two SUSY parameters free to vary: the pseudoscalar Higgs boson mass m_A and the tanβ.
- Chosen values for the rest of the MSSM parameters:

$$M_{susy} = 1\,\mathrm{TeV}/c^2$$
$$\mu = 200\,\mathrm{GeV}/c^2$$
$$M_2 = 200\,\mathrm{GeV}/c^2$$
$$M_{\tilde{g}} = 800\,\mathrm{GeV}/c^2$$
$$A_t = \sqrt{6}M_{susy} + \mu/\tan\beta$$
$$A_b = A_t$$

Production and decay of MSSM Higgs I

m_A (GeV/c^2) / tanβ	150.	200.	250.	300.	350.	400.	450.	500.
A								
10	19.4	7.37	3.31	1.65	.882	.505	.306	.189
15	43.7	16.6	7.45	3.72	1.99	1.14	.688	.426
20	77.7	29.5	13.2	6.62	3.53	2.02	1.22	.756
30	175.	66.4	29.8	**14.9**	7.94	4.55	2.75	1.70
40	311.	118.	53.0	26.5	14.1	8.08	4.89	3.03
50	486.	184.	82.7	41.4	22.1	12.6	7.64	4.73
H								
10	17.0	6.96	3.23	1.62	.881	.502	.302	.189
15	40.5	16.1	7.36	3.70	1.95	1.13	.683	.433
20	74.1	28.5	13.2	6.60	3.51	2.01	1.22	.757
30	170.	64.6	29.8	**14.9**	7.99	4.56	2.75	1.71
40	307.	116.	53.1	26.4	14.0	8.09	4.87	3.06
50	481.	183.	82.2	41.2	22.1	12.6	7.61	4.73

Cross section for the **associated production** of the bbA/H in **pb**.

The calculation is performed with the program HQQ.

Production and decay of MSSM Higgs II

tanβ	A	H
1.5	10.3	4.53
3.0	2.35	1.56
10.	.210	.647
15.	.455	.931
20.	.938	1.41
30.	2.42	2.82
40.	4.52	4.82
50.	7.24	7.39

Cross section for the **direct production** of 300 GeV/c^2 A/H in pb.
The calculation is performed with the program higlu.

Production and decay of MSSM Higgs III

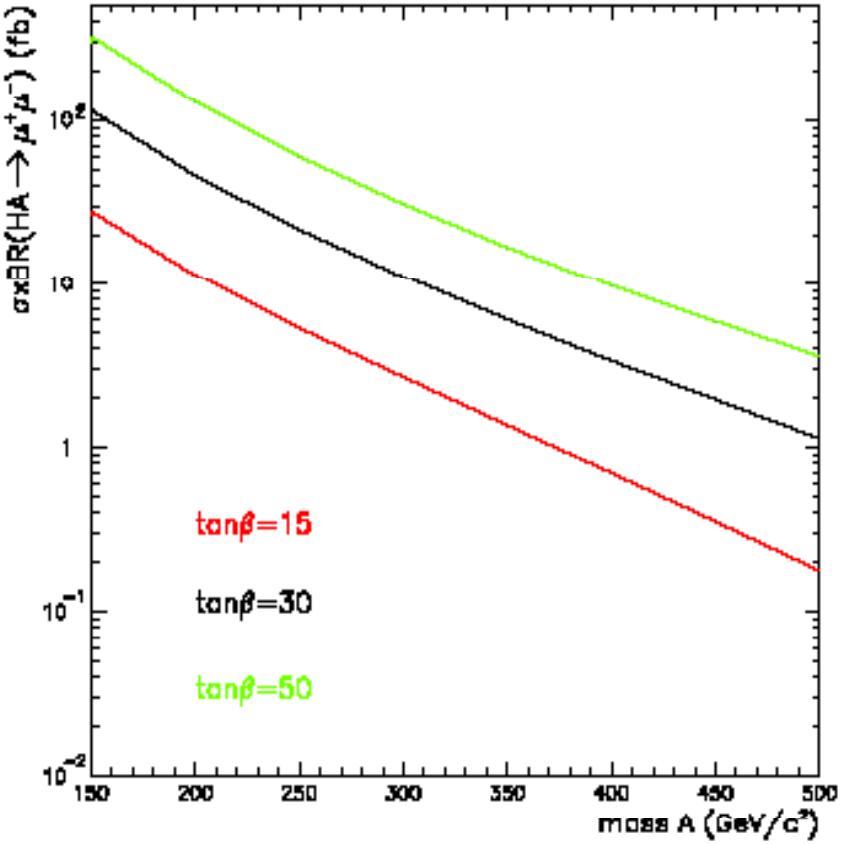
tanβ \ m_A (GeV/c²)	150.	200.	250.	300.	350.	400.	450.	500.
A								
10	6.44	2.56	1.17	.568	.272	.111	.051	.023
15	14.5	5.79	2.67	1.34	.689	.346	.176	.087
20	25.8	10.3	4.78	2.42	1.28	.686	.374	.200
30	58.1	23.2	10.8	5.52	2.96	1.67	.972	.560
40	103.	41.2	19.2	9.86	5.34	3.06	1.82	1.09
50	161.	64.4	30.0	15.4	8.39	4.84	2.92	1.77
H								
10	5.63	2.35	1.12	.528	.259	.116	.052	.023
15	13.5	5.58	2.63	1.32	.667	.346	.176	.089
20	24.7	9.93	4.76	2.41	1.26	.684	.375	.200
30	56.6	22.6	10.8	5.52	2.98	1.68	.971	.562
40	102.	40.5	19.3	9.83	5.29	3.06	1.81	1.10
50	160.	63.9	29.8	15.4	8.40	4.82	2.90	1.77

The σ x BR for bbH/A→mumu in **fb**

Production and decay of MSSM Higgs IV

Comparison of the cross sections:

- associated production dominates at high tanβ ; the direct may be important at low tanβ region
- A and H associated production x-sections almost identical => enlarging experimental discovery potential.
- A and H branching ratios to μμ pair very similar in the parametric space considered.



σ x BR for bb(H+A)→mumu

Signal and background samples

- FULL SIMULATION -

Signal:

Associated production of A boson decaying to 2 muons, $b\bar{b}A \rightarrow \mu\mu$

(m_A=300 GeV/c^2, tanβ=30)

Background:

- $Z/\gamma^* \rightarrow \mu\mu$ Drell-Yan production
- $t\bar{t}$ production (with $t \rightarrow Wb$ and $W \rightarrow \mu\nu$)
- $Zb\bar{b}$ production (with $Z \rightarrow \mu\mu$)
- ZZ production with muons in final state

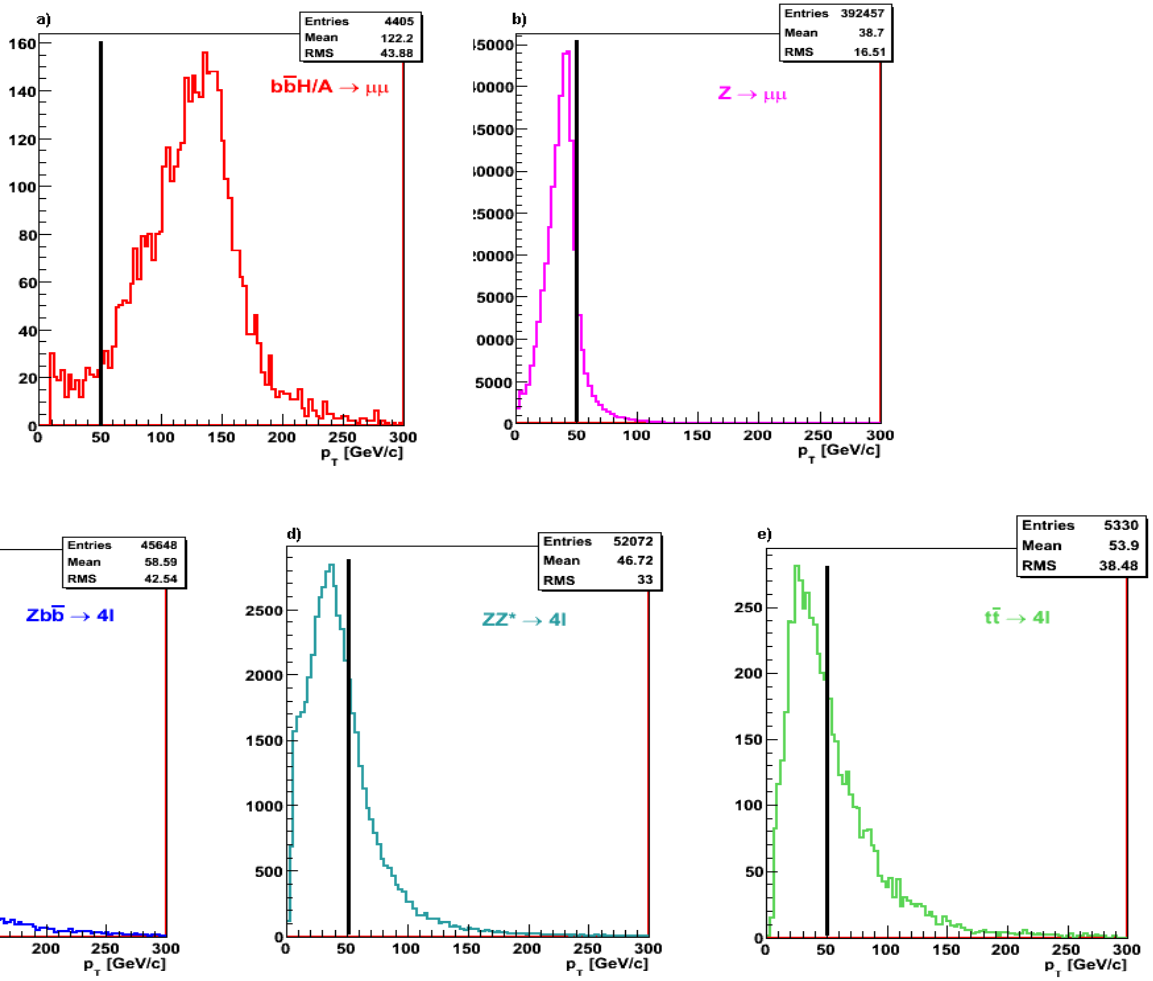
Analysis strategy

- Look at the p_T muon, p_T dimuon, p_T missing distributions, b-jets…and find the best combination of the cuts
- Ask for isolated muons (cluster energy deposition and # ID tracks used)
- Look at the acoplanarity of the muons → effective if muons are coming from different objects (W^+, W^- in ttbar events)

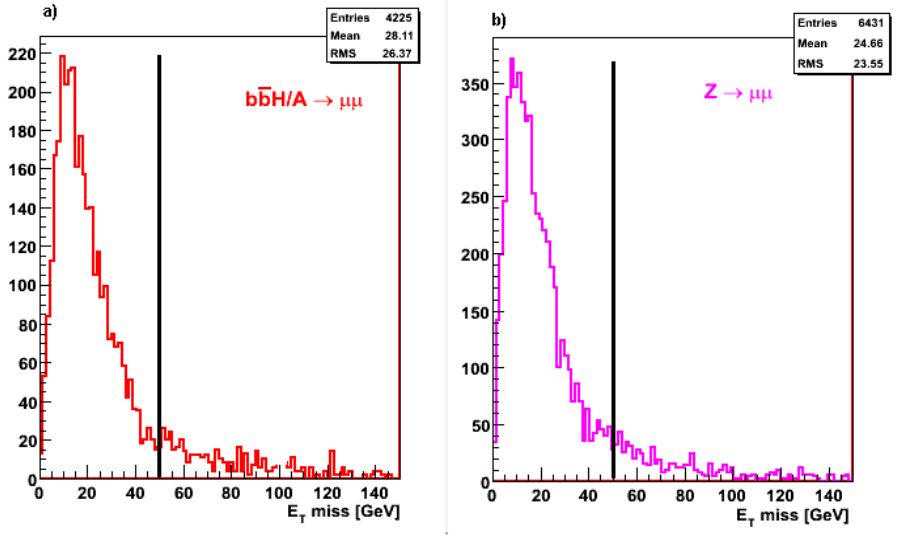
- TWO ANALYSES proposed for the optimization of background reduction (according to two production mechanisms of the H/A boson – direct, associated with bbar)

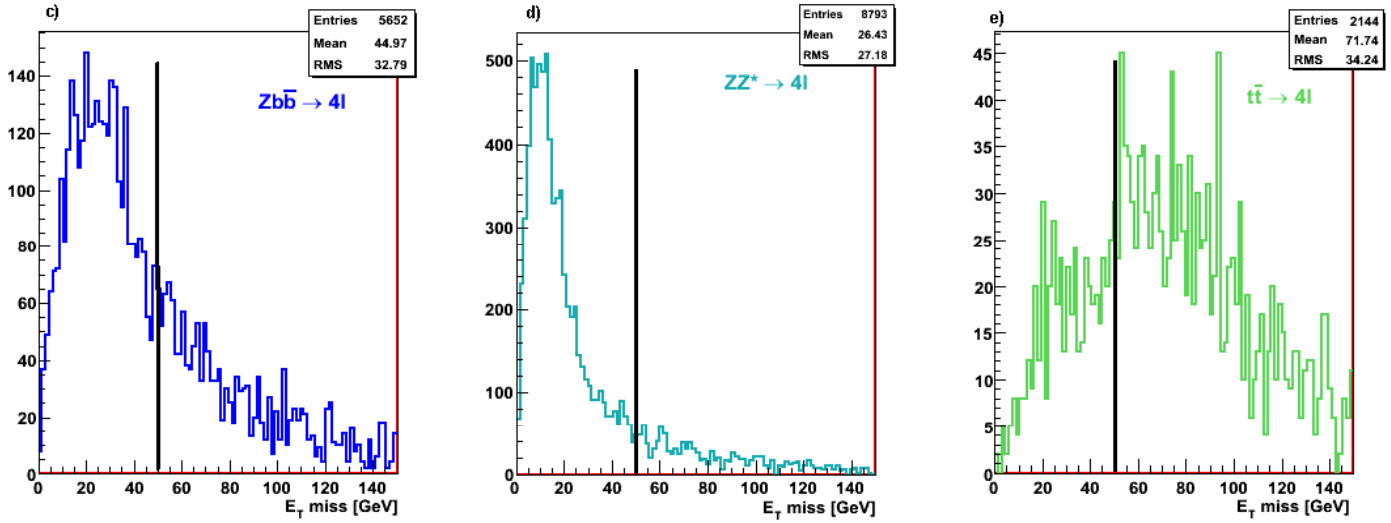
- Since no direct production samples were generated with full simulation, the efficiency of the cuts estimated using the:
  - kinematics from fast simulation (ATLFAST)
  - corresponding eff. of the irreducible background
  - ratio of the associated events passing each analysis set

p_T muon distributions for signal and background events

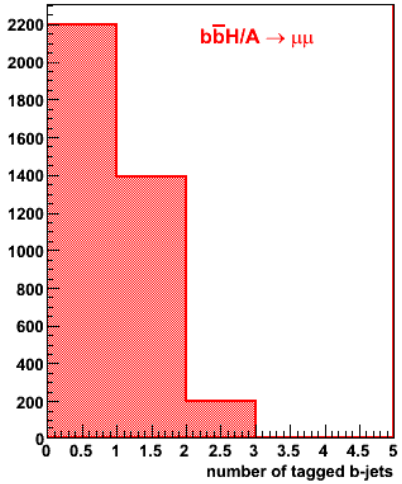


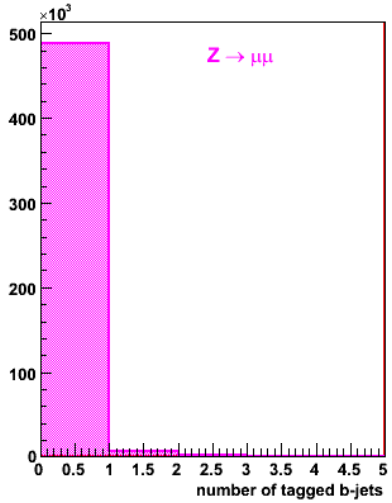
Missing energy distributions for signal and background events- after the p_T muon cut

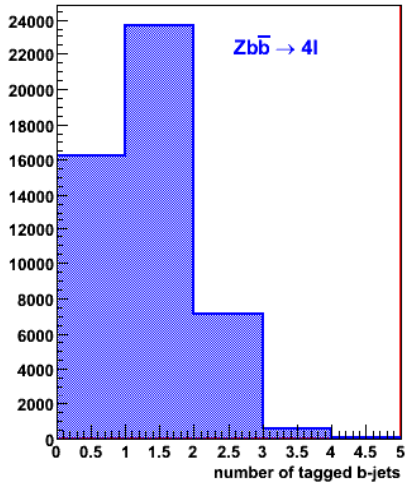


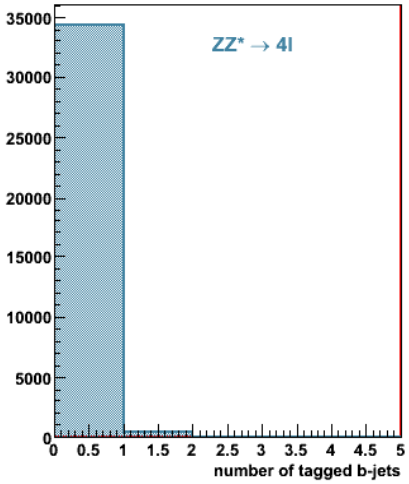


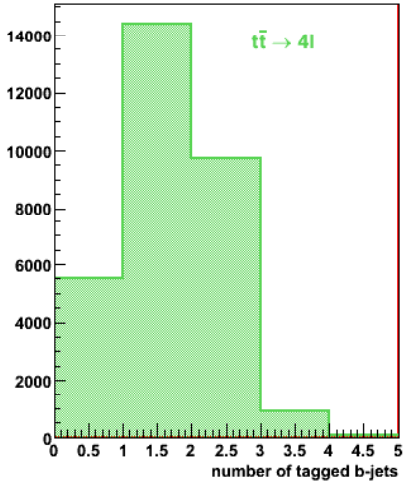
Number of tagged b-jets for signal and background events



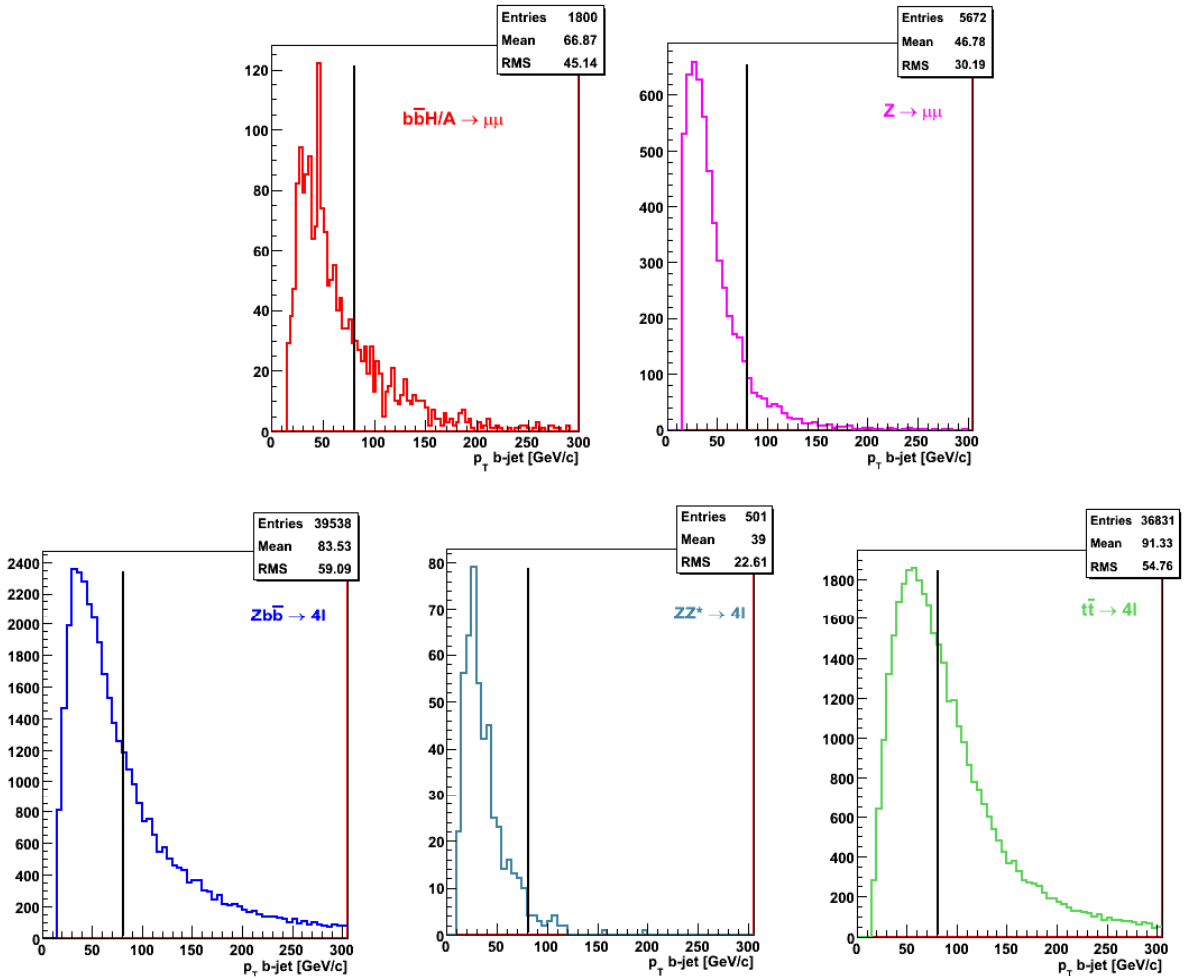




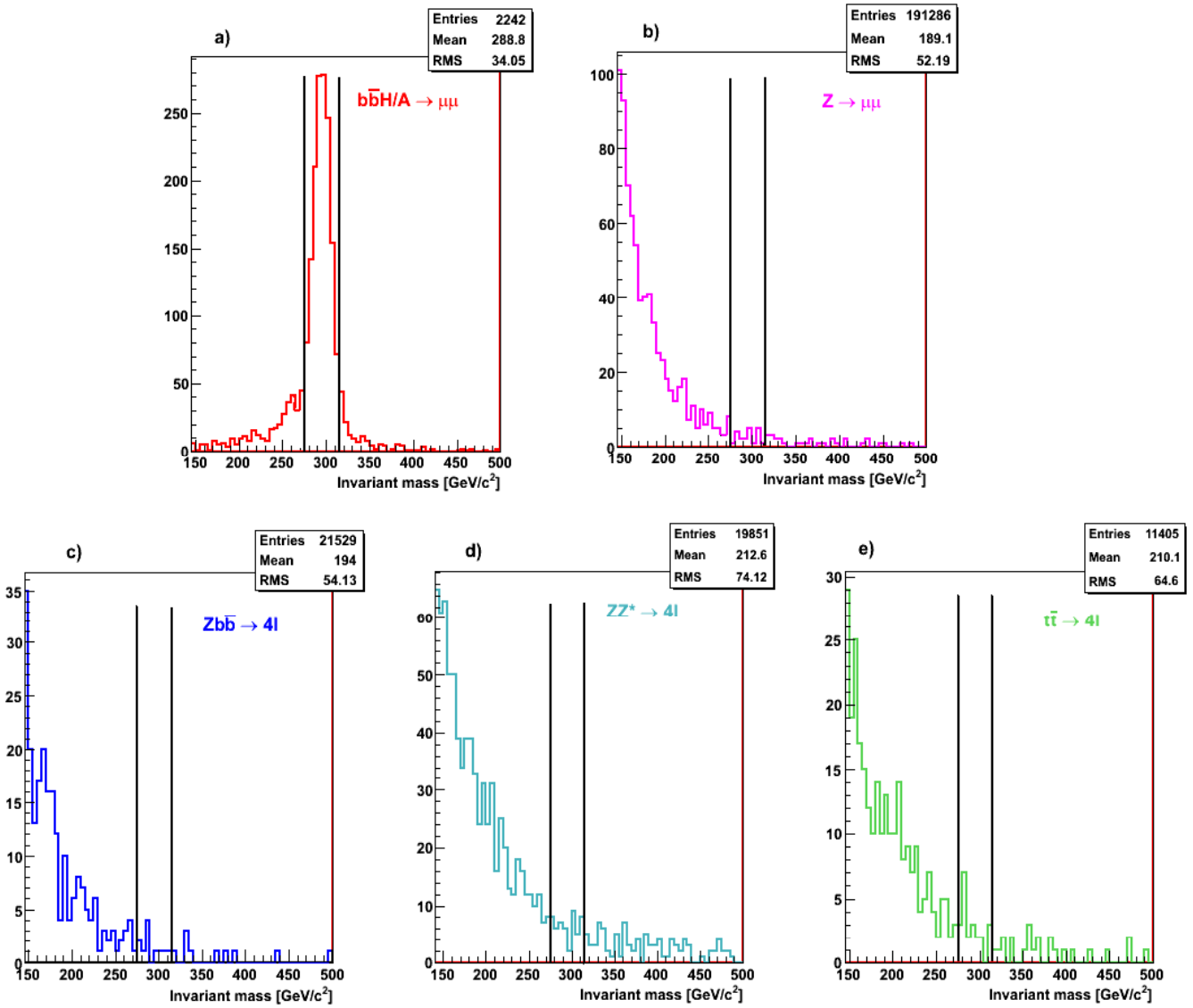




Transverse momentum of tagged b-jets for signal and background



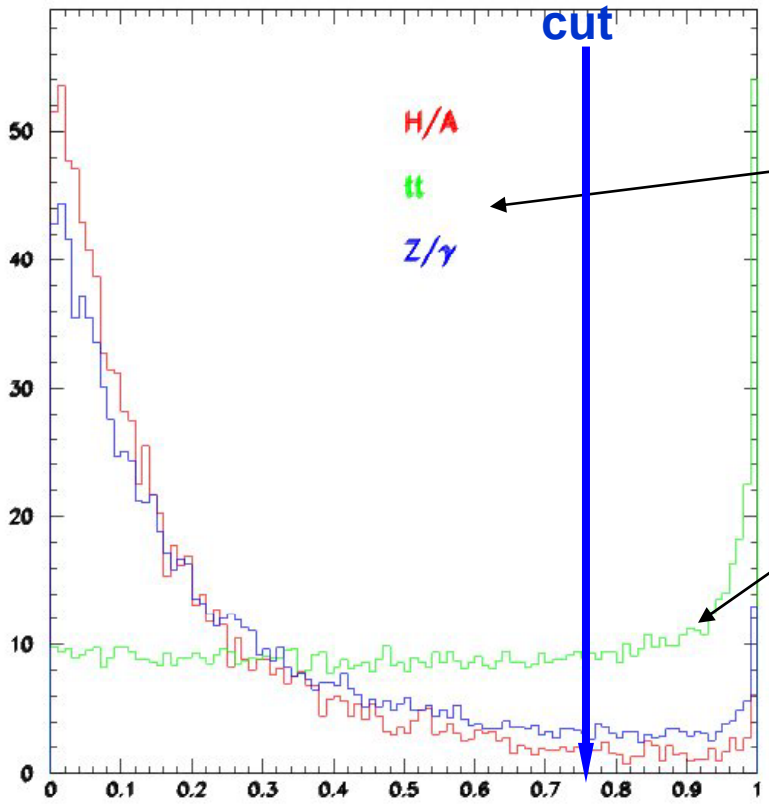
Invariant mass distributions for signal and background events



Acoplanarity studies

acoplanarity = $(z \times p_1)^* p_2$

Expressed as a *cos* of the angle



truth information-based acoplanarity distributions

Muons from W's selected in ttbar events

Useful tool to distinguish particles (muons) coming from the same or different objects!

The final sets of cuts

- Opposite sign μμ pair which passed the filter (geometrical acceptance).
- Both muons required to have p_T >50 GeV.
- p_T missing < 50 GeV: (effective in background events which have real missing energy, like ttbar).
- Muon isolation: only events where both muons have:
  no electromagnetic energy deposition > 5GeV and
  no more then 2 Inner Detector tracks
  accepted.
  } in cone $\Delta R<0.20$
- no p_T dimuon cut (the same rejection for signal and background) !
- Impact parameter cut analyzed as well; after previous cuts distributions similar for signal and background->this cut has not been applied !
- <u>ANALYSIS 1</u> (selects out the direct signal)
- - NO b-jets in events (b-jet veto).
- <u>ANALYSIS 2</u> (selects out the associated signal)
  - at least 1 tagged b-jet with 15 GeV/c < p_T < 80 GeV/c.
  - acoplanarity cut (additional rejection of ttbar events).
- $m_{\mu\mu}$ cut (±20 GeV).

Expected number of events for signal and background
L=30 fb^{-1}

process	σ x BR (*fb*)	Analysis 1	Analysis 2
H+A→μμ	**2**	**16**	**3**
bb(H+A)→μμ	**11**	**61**	**32**
Z/γ* →μμ	**1603 x 10^3**	**1141**	**16***
Zbb→ μμ	**39 x 10^3**	**1**	**18***
ZZ*→μμ	**547**	**15**	**0**
tt→μμ	**9.5 x 10^3**	**1**	**48**

* to avoid double-counting (since the Zbb production is already included in the Z/γ*production) we use only the number from the dedicated Zbb production.

SIGNAL SIGNIFICANCE

	Analysis 1	Analysis 2	Combined
$S/\sqrt{B}$	2.3	4.3	4.9

Summary

- The sensitivity of the ATLAS low luminosity running for the MSSM H/A bosons was studied.
- Both the direct and associated H/A productions considered (m_A=300 GeV/c^2, tanβ =30) and two different analyses proposed.
- The irreducible DY background dominates in the direct production case and overwhelms the signal for tanβ =30 → lower signal significance!
- For the associated production, the Zbb background is irreducible one, but the main one is ttbar → the selection criteria optimized for its reduction.
- For discovering the H/A boson with m_A=300GeV/c^2 and *tan β*>30, through its dimuon decay channel at more than the three sigma level, about a year of running at the low luminosity is needed.