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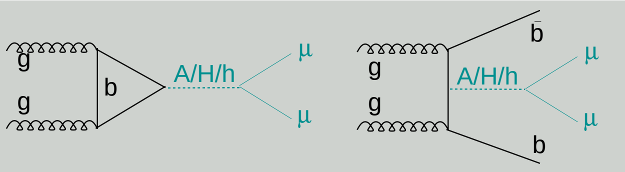
Search for the neutral MSSM Higgs bosons in the channel $A/H/h \rightarrow \mu^+\mu^-$



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Introduction

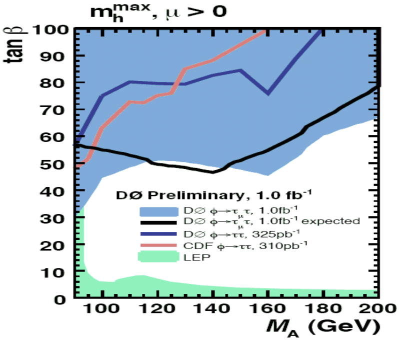
MSSM Higgs sector: five Higgs bosons ($H^{\pm}, A, H, h$).

LEP/TEVATRON limits:

$m_{A/h}$ >93 GeV/c^2,
$2 < \tan\beta < 60$.

Motivation for $A/H/h \rightarrow \mu^+\mu^-$:

Very clean channel,
not visible in SM,
enhanced in MSSM.



Outline (preliminary results of the CSC HG8 note):

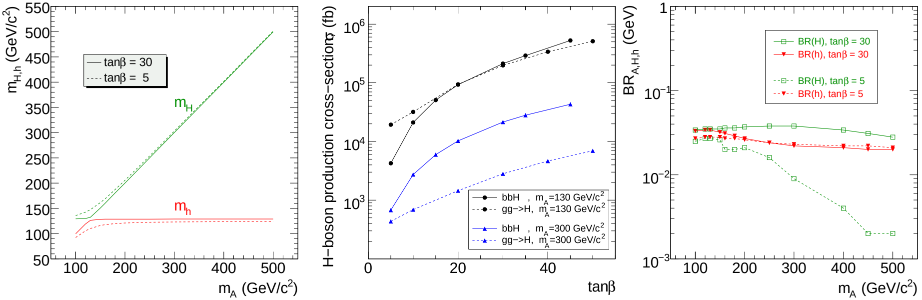
- Signal and background processes.
- Event selection.
- Detector-related systematic uncertainties.
- Estimation of the background from the real data.
- Discovery potential.

Signal processes

Two production modes:

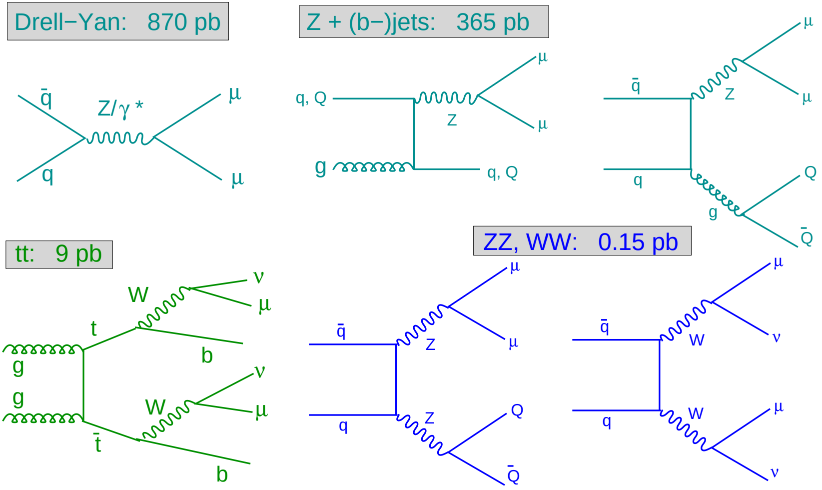
- Direct production, SM-equivalent: $gg \to A/H/h$.
- Associated production: $(gg, qq) \to bbA/H/h$.

All Higgs properties determined (at tree-level) by m_A and $\tan\beta$:



- A/H degenerate in mass for m_A >130 GeV (A/h for <130 GeV).
- Associated production dominant at higher masses and $\tan\beta$-values.
- A/H-branching ratio into $\mu^+\mu^-$ increases with $\tan\beta$.

$\Rightarrow$ $\sigma \times BR \approx$ (1 - 500) fb.

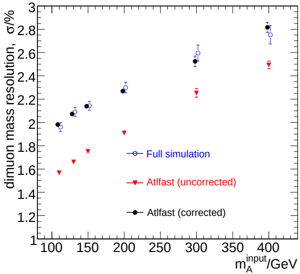


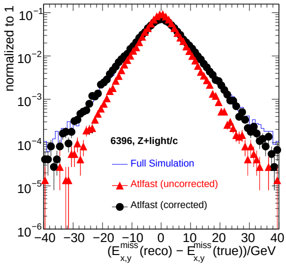
Signal simulated with full simulation.
Dominant backgrounds simulated using Atlfast (∼70M events).
Atlfast parametrization tuned offline to reproduce the full simulation.

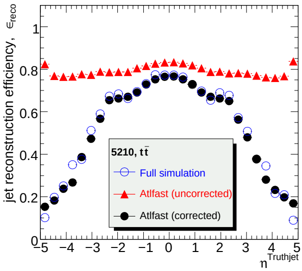
Atlfast tunning to the full simulation

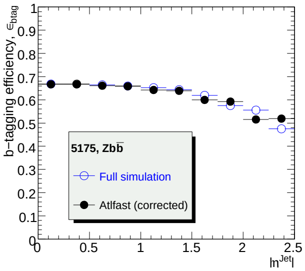
Original Atlfast parametrization is obsolete,
due to the software modifications in the full simulation.

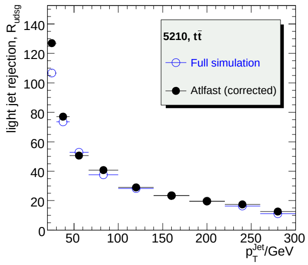
$\Rightarrow$ Corrected offline, using dedicated fully simulated datasets.







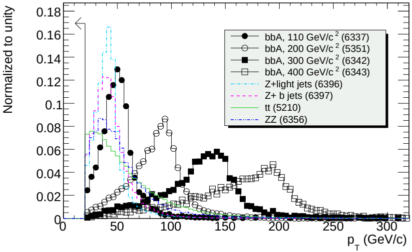


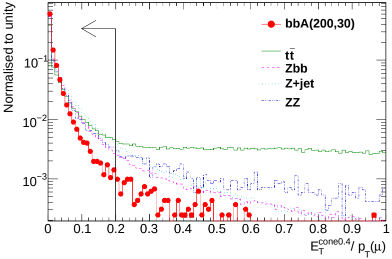


Event selection

Preselection:

two isolated muons (μ^+, μ^-); $p_T > 20$ GeV/c, $|\eta| < 2.7$.





Analysis (A):
no b-tagging requirement.

- Final state with 0 jets.
- Final state with 1 jet.

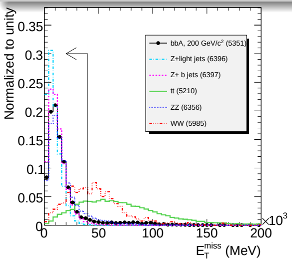
Analysis (B):
with b-tagging requirement.

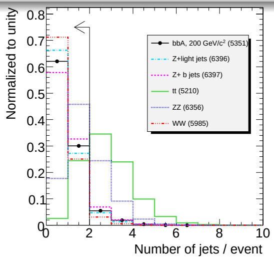
- Final state with 0 b-jets.
- Final state with ≥1 b-jet.

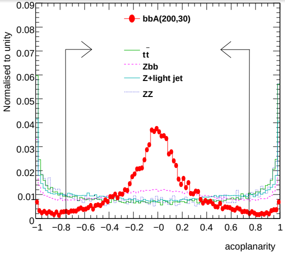
Trigger selection efficiency for the events passing all analysis cuts.

Discriminating variables

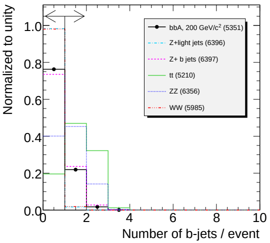
Without b-tagging: E_T^{miss}, jet multiplicity, acoplanarity$= \frac{p^{\mu}_{x1}\cdot p^{\mu}_{y2} - p^{\mu}_{x2}\cdot p^{\mu}_{y1}}{p^{\mu}_{T1}\cdot p^{\mu}_{T2}}$.

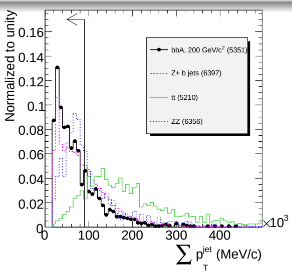






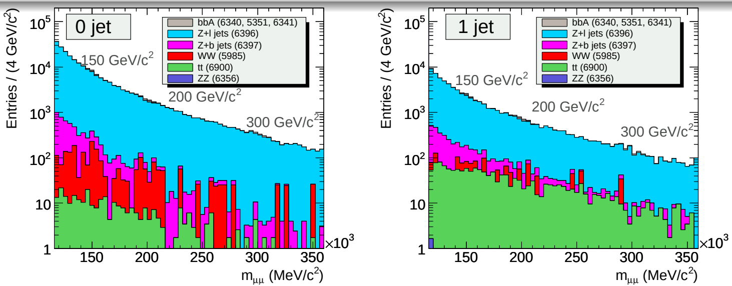
With b-tagging: E_T^{miss}, b-jet multiplicity, acoplanarity, $\sum p_T^{jets}$.



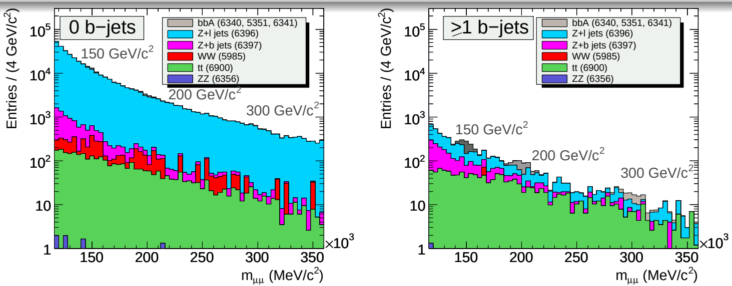


Analysis results

Analysis (A): no b-tagging.

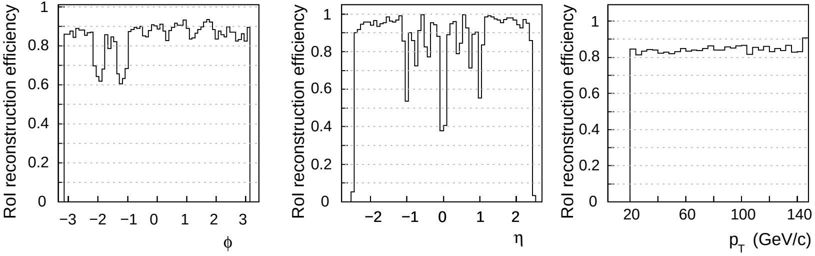


Analysis (B): with b-tagging.



Trigger selection efficiencies

Fraction of muons with $p_T > 20$ GeV/c, which have a RoI (Level-1): (acceptance holes in the feet region and at $|\eta| = 0$).



- Single high-p_T muon trigger (μ20): ~95% trigger selection.

Dataset	m_A (GeV/c^2)	Level-1	High level trigger
$b\bar{b}A$, 150 GeV/c^2	150	97.4	95.8
$b\bar{b}A$, 200 GeV/c^2	200	97.2	95.0
$b\bar{b}A$, 300 GeV/c^2	300	97.1	94.7
$b\bar{b}A$, 400 GeV/c^2	400	96.4	96.3
$t\bar{t}$		97.1	95.1
$b\bar{b}Z$		97.1	94.8

Detector related systematic uncertainties

Using the common ATLAS estimations for the detector uncertainties:

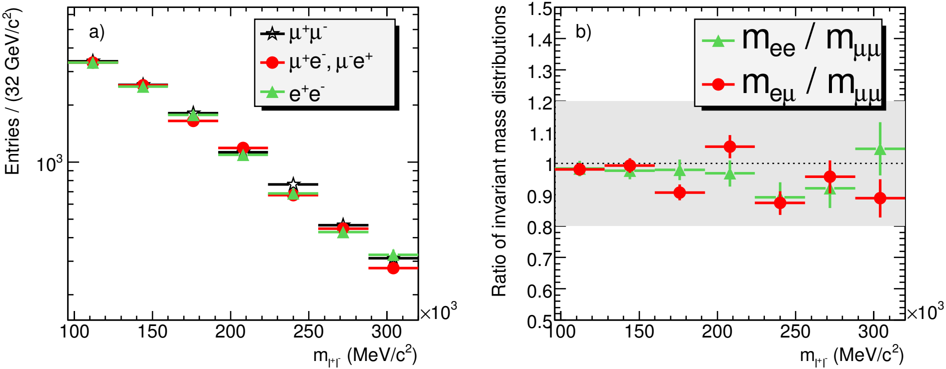
Systematic uncertainty		$bbA(200)$	$t\bar{t}$	$Z + b$ jets	$Z +$ light jets
		$m_{\mu\mu}$ >100 GeV/c^2			
Muon resol.	$\sigma(\frac{1}{p_T}) = \frac{0.011}{p_T} \oplus 0.00017$	-1.5	0.0	1.5	1.5
Muon p_T scale	$\pm1\%$	±2.3	±1.7	±10.0	±11.2
Muon efficiency	$\pm1\%$	±1.9	±1.3	±2.1	±2.1
Jet energy resol.	$\sigma(E) = 0.45(0.63) \cdot \sqrt{E}$	-1.5	-11.7	-1.2	-1.0
Jet energy scale	$\pm7\%(\pm15\%)$	±1.2	±13.4	±1.9	±5.1
b-tag efficiency	$\pm5\%$	±3.6	±2.2	±2.7	±0.3
b-tag fake rate	$\pm50\%$	±0.8	±0.0	±1.1	±45.4
Total		5.3	18.1	11.0	45.8

- Largest effect: uncertainty of the b-tagging fake rate, affects the dominant $Z +$ *light jets* background.
- $t\bar{t}$-background sensitive to the jet energy scale and resolution.
- Z-background sensitive to the muon p_T-scale (for $m_{\mu\mu}$ <130 GeV/c^2).

Background estimation from data: e^+e^-, $e^\pm\mu^\mp$

Contrary to $\mu^+\mu^-$ final state, no signal is expected for e^+e^- or $e^\pm\mu^\mp$.
Possible differences: electron efficiency/resolution, overlap with jets.

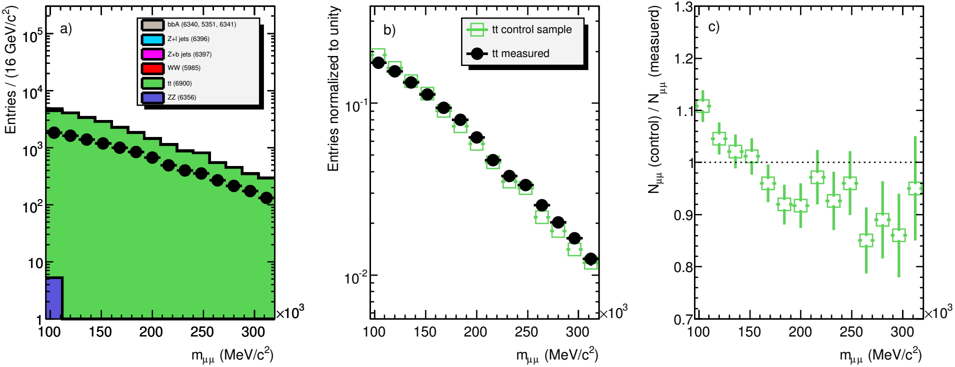
- For the comparison of $Z \rightarrow e^+e^-$ and $Z \rightarrow \mu^+\mu^-$ signatures, we reffer to ATLAS-PHYS-PUB-2006-019 (S.Gentille et al.).
- In the HG8 note, we concentrate on the $t\bar{t}$-background:
  - $\sim$10% accuracy after correcting for μ.vs.e-efficiencies (30 fb^{-1}).



Background estimation from data: $t\bar{t}$ control sample

Pure $t\bar{t}$ control sample obtained by inverting the cut on E_T^{miss}: requiring E_T^{miss} >60 GeV instead of usual E_T^{miss} <40 GeV.

$\Rightarrow$ can be used for the additional check of the $t\bar{t}$-shape.



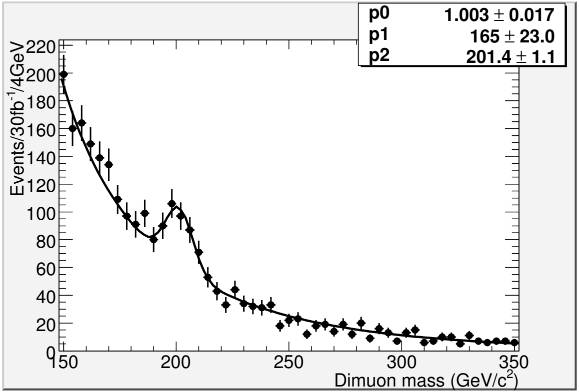
Signal significance (from the fit to the data)

Following function is fitted to the dimuon distribution:

$$f_{total}(p_0, p_1, p_2) = p_0 \cdot f_{background} + p_1 \cdot f_{signal}, \quad where$$

$$f_{signal}(p_2) = \frac{1}{\sigma(p_2)\sqrt{2\pi}} \cdot exp\left(-\frac{(x-p_2)^2}{2\sigma^2}\right) \quad (p_2 - Higgs\ mass\ in\ a\ given\ window)$$

$$f_{background}(a_1, a_2, a_3) = \frac{a_1}{x} \cdot \left[\frac{1}{(x^2-M_Z^2)+M_Z^2\Gamma_Z^2} + a_2 \cdot exp(-a_3 \cdot x)\right].$$



a_1:
normalization scale
determined from side bands

a_2, a_3:
determined from
e^+e^- and $e^\pm\mu^\mp$ signatures,
errors on $a_{2,3}$ calculated
as difference w.r.t. $\mu^+\mu^-$

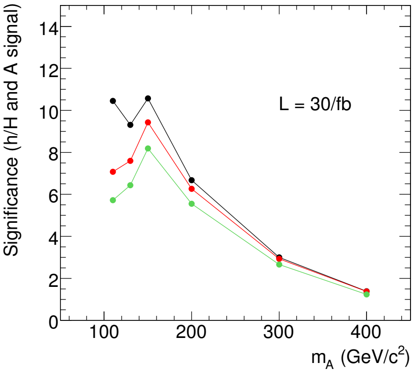
Discovery potential

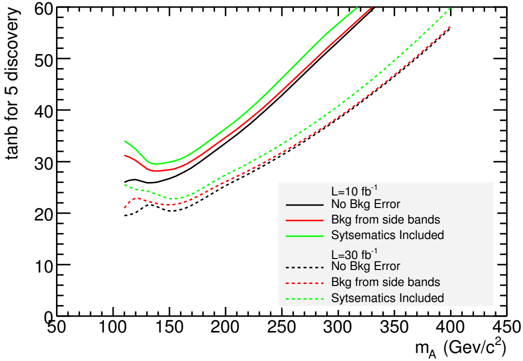
Signal significance calculated using the profile likelihood method:

a) from Monte Carlo (fixed mass window, no error on background)

b) from the fit (fixed mass window so far, bckg. error of $10\%/\sqrt{\mathcal{L}}$)

c) = b) + systematic uncertainties





- Obtained result similar to the one obtained in the TDR.